VOLUME 61 [W. B. No. 1109] NUMBER 7

MONTHLY WEATHER REVIEW

JULY 1933

CONTENTS

	Page
American Pioneers in Meteorology. Eric R. Miller	189
A Brief List of Works on Meteorology. C. Fitzhugh Talman	194
Weather Types and Pressure Anomalies. (10 figs.) Thomas A. Blair	196
The Upward Speed of an Air Current Necessary to Sustain a Hailstone. George Grimminger	198
A Brilliant Meteor and Its Cloud-like Trail. (1 fig.) Samuel P. Peterson	200
Tropical Disturbances of July 1933. Charles L. Mitchell	200
The Dallas, Tex., Tornado of July 30, 1933. (2 figs.) Gorden E. Dunn	201
Excessive Rainfall of July 22–25, 1933 in Louisiana and Extreme Eastern Texas. (1 fig.) Ray A. Dyke	202
Bibliography	203
Solar Observations	203
Aerological Observations	205
Rivers and Floods	207
Weather on the Atlantic and Pacific Oceans	208
Climatological Tables	211
Charts I–VI and VIII–XI. (Chart VII (snowfall) used only in snow season.)	

UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
WASHINGTON, D.C.

For sale by the Superintendent of Documents, Washington, D.C. - - - - - - - - - - - - - - - - See page 4 of cover for prices

CORRECTIONS

Volume 61, April 1933, page 108: Table 1, fourth column, thirteenth line from bottom "1242.5" should be "1247.5"; next column, twelfth line down, "14" should be "13"; next column, twelfth line from bottom, "–3.6" should be "–0.6". Same page, table 4, second boxhead, "32" should be "37"; same table, tenth column "900" should be "990". Table 2, column 6, "885" should be "895"; same table, tenth column, "1682" should be "1692."

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

Vol. 61, No. 7
W. B. No. 1109

JULY 1933

Closed September 5, 1933
Issued October 13, 1933

AMERICAN PIONEERS IN METEOROLOGY [1]

By Eric R. Miller

[Weather Bureau Office, Madison, Wis., June 1933]

Pioneer weather observers.—The early colonists found the weather and climate of this continent a source of interest, and sometimes of surprise. The educated recorded the weather in their diaries and included it in their letters to the old country. One of these diarists, the Rev. John Campanius, of New Sweden, is acclaimed "first American weather observer" by Marcus Benjamin in the chapter on meteorology of the jubilee volume of the Smithsonian Institution, 1896. The diary kept by Campanius for the years 1644–45 at a fort near the present site of Wilmington, Del., was published by his grandson. Very few of such noninstrumental records have been published in this country, although, as Hellmann has shown, much can be gleaned from them.

Instruments for the quantitative measurement of the weather elements were rare in colonial times. The first were imported by Dr. John Lining, an eminent physician who migrated from Scotland to Charleston, S.C. in 1730. He imported a barometer, thermometers, hygrometer, and rain gage, and undertook systematic tridaily observations to ascertain the influence of atmospheric conditions on the human body, and upon the incidence of epidemic diseases. The history of these early observers has been written by Henry,[2] McAdie,[3] Varney,[4] and Abbe,[5] and their records have been collected and summarized by Schott.[6]

Founders of early weather services.—Hygienic climatology was the object of the first American weather service, that of the Army Medical Department, founded 1814, by an unobtrusive clause in the regulations issued by James Tilton, physician and Surgeon-General, Revolutionary War veteran, and member of the Continental Congress. The effect of this initiation of meteorological work was not important until the Army was expanded by John C. Calhoun, Secretary of War, to bring the Middle West and the Louisiana Purchase under the control of the Government. Then the meteorological service began a march with the frontier that ultimately carried it across the continent, and thus afforded us the first outlines of the climate of the country as a whole.

Another Revolutionary soldier whose hobby of weather observing led to the establishment of a weather service, was Simeon Dewitt, successively chief topographical engineer on the staff of General Washington, surveyor general of the State of New York, and vice chancellor of the University of the State of New York. In the latter capacity, he organized meteorological observations at the academies throughout the State, which continued from 1825 to 1863. This bureau performed noteworthy service in designing and testing instruments (the DeWitt rain gage was adopted by the Smithsonian meteorological system), and in training men like Joseph Henry, and James H. Coffin to do meteorological work.

Discovery of the law of storms and invention of the weather map.—One of those rare outbursts of intense activity in research and discovery that bring more progress in a decade than had occurred in the preceding millenium was going on in meteorology just a century ago.

One circumstance that stimulated progress here at that time was the beginning of the publication in this country of scientific journals. Aside from the Transactions of the American Philosophical Society (1771) the first of these was the American Journal of Science, founded by Benjamin Silliman of Yale in 1818, next the Journal of the Franklin Institute in 1826, and then the Proceedings of the American Philosophical Society in 1840.

The formative period of American meteorology has been well sketched by the eminent mathematician Maxime Bôcher, and I quote from his paper "The Meteorological Labors of Dove, Redfield, and Espy" (Am. Met'l Jol. 5, 1888, 1–13):

"The subjects which occupied the minds of meteorologists at the time to the exclusion of everything else was the theory of storms, both of wind and of rain, a region in which they found the paths as yet almost untrodden. The preceding meteorologists had done some valuable work, of which the most important was perhaps Hadley's (George Hadley, Concerning the Cause of the General Trade Winds, Phil. Trans. Vol. 39, pp. 58–63, 1735) partially correct explanation of the trade winds of the Torrid Zone [partially because he assumed the velocity of the air around the axis of the earth to remain constant with change of latitude, except as affected by friction with the surface of the earth, instead of inversely proportional to its distance from that axis, as it tends to be in accordance with the law of the conservation of areas. Also he neglected—it was not then known—the equal tendency of the air to deflect from its course whatever its horizontal direction.] They had not even a correct understanding of the motions of the atmosphere in a

---

[1] Presented at the meeting of the American Meteorological Society at the Century of Progress Exposition, Chicago, June 1933.

[2] Henry, A. J. Early individual observers in the United States. W.B. Bull. 11, 1893, 291–302.

[3] McAdie, A. Simultaneous meteorological observations in the United States during the 18th century. W.B. Bull. 11, 1893, 303–304.

[4] Varney, B. M. Early meteorology at Harvard College, Mo. Wea. Rev. vol. 36, 1908, 140–142, 286–290.

[5] Abbe, C. Chronological outline of the history of meteorology in the United States, Mo. Wea. Rev. vol. 37, 1909, 87–89.

[6] Schott, C. A. Tables and results of the precipitation in rain and snow in the United States and at some stations in the adjacent parts of North America and in Central and South America. Smithsonian Contr. to Know. 1st Ed. 1872, 2d ed. no. 353, 1881. Tables, distribution and variations of the atmospheric temperature in the United States and some adjacent parts of America. Smithsonian Contrib. to Know. no. 277, 1876.

storm, much less could they explain them. In regard to rainstorms, however, there was one plausible theory, that of Hutton (James Hutton, 1726–97, Theory of Rain Edin. Trans. 1, 1788) who had shown that when two masses of air at different temperatures are mixed together, a portion of their moisture may be precipitated, so that the meeting of a warm and a cold wind would be the cause of a rainstorm. With the exception of this, we may fairly say that nothing was known about storms except that a northeast gale on our coast 'backs up' against the wind. (C.f. W. M. Davis, Was Lewis Evans or Benjamin Franklin the First to Recognize that Our Northeast Storms Come from the Southwest? Proc. Am. Phil. Soc. 45, 1906, 129–130.)

"In 1821, William C. Redfield, a mechanic (saddler) by trade with only a common-school education, had occasion to go from his home in Connecticut to the western part of Massachusetts, over the very region which a few months before had been swept by a violent September gale. The wind had left its record in the fallen trees, and as Redfield advanced and found the trees lying in the opposite direction to those near his home, it flashed upon him that the gale was a whirlwind on a large scale which advanced over the country from southwest to northeast, while at the same time it whirled around its axis in a direction opposite to that in which the hands of a watch move. This was Redfield's great discovery. However, he was a diffident young man, and it was only through a chance meeting with Prof. Olmsted of Yale, that he was induced to write an account of his theory of storms. It was not until the year 1831 that he was able to publish his first meteorological paper, Remarks on the Prevailing Storms of the Atlantic Coast and of the Northeastern States (Am.J.Sci. 20, 1831, 1–36). This article is devoted in great part to the storm of 10 years before and contains a considerable number of independent observations extending over all our Atlantic coast. He thus puts his whirlwind theory on a firm foundation and also makes his second great discovery, that these storms move, roughly, in a parabolic path. These two important principles are here established independent of any theory."

"However decisive the array of facts brought forth in these early papers may appear to us, it seems to have been very far from carrying conviction to the minds of several contemporary meteorologists. Of these the most notable was Espy (James Pollard Espy, 1785–1860) who from this time forth appears as the persistent opponent of Redfield both as to facts and theory." Neither Redfield nor Espy was aware of "Hadley's principle" of the deflective effect of the earth's rotation. Espy, who was well grounded in the physics of his day, could not admit the rotation observed by Redfield because he knew of no force capable of producing it, but insisted that the wind always blows inward from the edge of the storm to a central point or line. Espy's contributions to meteorology were chiefly the theory of convection and the thermodynamics of moist air in vertical motion. As early as 1828, Espy had seen the importance of water vapor, but it was not until 1836 that he first made known his theory of storms in some papers published in the Journal of the Franklin Institute. As there stated his theory is as follows: "When a portion of transparent vapor in the air is condensed into cloud or water, the latent caloric given out expands it six times as much as it is contracted by the condensation of vapor into water" so that "the moment a portion of vapor begins to condense into cloud, the air in which it is contained begins to expand, and consequently if an equilibrium existed before, it is now destroyed and the cloud will continue to ascend so long as its temperature is greater than that of the surrounding air." Espy argued that "as this air rises other air will rush in from all sides to take its place, and this in turn will rise, thus forming what Espy calls a vortex, near whose center there will usually be rain, and toward whose center the wind will blow. Moreover Espy's theory explained not only a windstorm with a rainy center, but also a hailstorm when the raindrops carried upward until congealed are thrown out at one side, and waterspouts and landspouts, which are merely small vortices of unusual violence which reach down to the ground with their accompanying cloud, and lastly but most important of all, the diminution of barometric pressure at the center of storms, for we have here a column of relatively warm and consequently light air."

Redfield, as early as 1834, expressed the opinion that the typhoons of the China Sea were similar to West Indian hurricanes; that the storms of the Southern Hemisphere would be found to rotate in the opposite direction to those of the Northern Hemisphere, and to follow paths recurving in the opposite direction from the Equator; all of which were found to be true a few years later when the facts were investigated.

Redfield was fortunate in his proselytes. The first of these was Lt. Col. William Reid (1791–1858) who had won reputation in Spain under Wellington. Reid came out to Barbadoes as governor in 1831 just after that island had been devastated by a hurricane. Redfield's first paper came into his hands at that time, with the result that he entered into correspondence with Redfield (three volumes of which are said by Reid's biographer to be in Yale University), and devoted many years to the study of tropical storms, and the formulation of the "law of storms" to enable seamen to escape destruction. After returning to England, Reid had the East India Co. assign to Captain H. Piddington, curator of a museum in Calcutta (1797–1858) the duty of studying the storms of the Indian seas. Piddington coined the word "cyclone" and in 1848 published that popular treatise on maritime meteorology, "The sailor's hornbook of storms in all parts of the world." This torch of research was handed on to the island of Mauritius, where Thom and Meldrum worked out the peculiarities of the cyclones of the South Indian Ocean.

Espy also built up a more local circle of collaborators. The American Philosophical Society and the Franklin Institute supported a joint committee of influential men, of which Espy, and later Dr. Dunglison, was chairman. This committee in 1834 organized a net of observing stations covering the Atlantic and Gulf States, and the Ohio Valley from Canada to Louisiana, and began collecting data and mapping storms. The committee obtained a grant of $4,000 from the Pennsylvania legislature in 1837 to be expended in equipping one observer in each county of the State with a barometer, two ordinary thermometers and a self-registering theremometer, and a rain-gage.

Espy went to Europe in 1840 to explain his theory of storms. His address before the British association was discussed by Sir John Herschel and Sir David Brewster, and published in the report of the association for 1840. In France he met a most enthusiastic reception. Introducing him to the Academy of Science, Arago placed Espy on a par with Newton. His "Brief outline of the theory of storms" was commended by the academy and published in the Comptes Rendus, 1841, p. 454. Coincident with his return to Boston, Espy's "Philosophy of Storms" came from the press. This is an elaborate presentation of his theories, supported by numerous instances, with

applications to the explanation of many atmospheric phenomena. In later years, it has been undeservedly neglected, with the result that others have received credit for discoveries that had already been made by Espy, e.g. the Koeppen-Espy theory of the daily march of wind velocity (cf. "Philosophy of Storms," p. xiv).

Elias Loomis (1811–89) followed with great interest the debate between Redfield and Espy, which was at its height in the years between his graduation from Yale in 1830 and entrance on his professorship of mathematics and physics at Western Reserve College near Cleveland, Ohio, in 1836. He was allowed to spend the first year of this professorship, 1836–37, in Paris where he attended the lectures of Biot, Poisson, Arago, Dulong, Pouillet, and others. After his return to the States, in addition to his teaching, he carried on original research in terrestrial magnetism, the aurora borealis, and meteorology, and set up and made important observations with astronomical, magnetic, and meteorological instruments, which he had bought in Europe. In studying all the circumstances of a tornado, Loomis was led to the discussion of two storms of great extent that occurred in 1836 and 1842, in papers read before the American Philosophical Society at Philadelphia. The second of these papers created a great sensation, because it published the first synoptic weather map of isobars and isotherms. A sketch of the vertical movements at the squall front, that appears in this paper, anticipates modern views with remarkable accuracy. Loomis in 1868 published his well-known textbook on meteorology, and after the beginning of the Signal Corps meteorological work, Loomis presented 18 "Contributions to meteorology" to as many successive semiannual meetings of the National Academy of Sciences, in which were brought together and discussed facts about the cyclones and anticyclones of the entire globe, and matters regarding the distribution of rain.

Paralleling, and in some cases antedating, the development of meteorological theory in America, attacks on the same problems were going on in other parts of the world. For example, Capper, in 1801, inferred that the tropical storms of the Coromandel coast of India were "whirlwinds whose diameter cannot be more than 120 miles" ("Observations on winds and monsoons") Romme ("Tableaux des vents, des marées et des courans"), 1806, describes a typhoon of the Gulf of Tonkin as a "tourbillon", and H. W. Brandes (1777–1834), then professor of mathematics at Breslau, later of physics at Leipzig, began in 1817 a study of the weather of each day of the year 1783, in which he prepared 365 charts with lines of equal deviation of the pressure from the normal, and arrows to show the direction of the wind. Unfortunately none of these charts were published, but Hildebrandsson has reconstructed one of them from the same data. H. W. Dove (1803–79), although 20 years younger than Redfield or Espy, began to write before either of them and continued until his death in 1879. His doctor's thesis "Ueber barometrische Minima" (Pogg. Ann. 13, 1828, 596), announces his theory of storms, which he connects with Hadley's theory of the trade winds by supposing that in the temperate and polar zones, polar and equatorial winds are placed side by side, instead of over one another as in the torrid zone. This part of Dove's theory, which Bôcher, 45 years ago, spoke of as exploded, is identical with the scheme of atmospheric circulation shown in the frontispiece to Hobb's "Glacial Anticyclones" 1926, and is not very different from the modern polar-front theory. There was active interchange of views between Dove, Redfield and Espy, without unseemly discussion as to who should have the honor of priority.

The work of these men brought into being the science of meteorology, as yet wholly qualitative, but capable of supporting a commercially valuable art, that of predicting storms.

The founding of national weather-forecasting services.—Of all these early meteorologists, Espy was most keenly alive to the possibility of practical applications. Immediately after his return from France in 1841, he proceeded to Washington with a plan for the establishment of a national weather service. The records of Congress show that he enlisted the support of some of the ablest statemen of that day, but the public was so tax-conscious that the most that was dared was to provide an irregular compensation for Espy by adding a last-moment amendment to one appropriation bill or another at session after session until the year before his death in 1860.

John Quincy Adams, a Member of the House (after his term as President of the United States) and well known for his interest in science—he had tried to secure an appropriation for the five meteorological and magnetic observatories asked by Sabine in 1839 in cooperation with the Antarctic Expedition of James Clark Ross, and was chairman of the Smithson bequest committee—says of Espy, (Memoirs, vol. 11 p. 52):

(January 6, 1842) "Mr. Espy, the storm breeder, who had notified me at Boston that he would be here at the beginning of the year, punctual to his time, appeared yesterday at the House, and requested me to fix a time for an interview. I appointed him 9 o'clock this morning. He left with me a paper exposing his three wishes of appropriations by Congress for his benefit—about as rational as those of Hans Carvel and his wife. The man is methodically monomaniac, and the dimensions of his organ of self-esteem have been swollen to the size of a goiter by a report of a committee of the National Institute of France endorsing all of his crackbrained discoveries in meteorology. I told him with all possible civility that it would be of no use to memorialize the House of Representatives in behalf of his three wishes. He said that he had thought of addressing the Senate, and asked if they should pass a bill in his favor whether I would support it in the House. I said that if the Senate should pass such a bill I would do all that I could for him in the House."

(January 19, 1842) "Meeting of the select Committee of the Smithsonian Bequest. Habersham presented a letter from James P. Espy, proposing that a portion of the fund should be appropriated for simultaneous meteorological observations all over the Union, with him for central national meteorologist stationed at Washington with a comfortable salary."

Although frustrated in his plan for a national weather service, Espy had positions in the Surgeon General's office and in the Navy Department, where he had the use of reports from military posts and from ships, in addition to the corps of volunteer civilian observers that he had organized at Philadelphia in 1834. From these he prepared four reports on meteorology, summarizing the laws of storms and illustrating by maps and graphs the progress of storms across the country. Adams refers to this work (vol. 11, p. 506, February 8, 1844) "Mr. Espy, the storm breeder, came with a complaint that the Committee on Ways and Means were about to retrench the appropriation for some small interloping office under the War Department with which he has been allowed for the

last 2 years to pursue the study of storms. He said that he had contemporaneous observations made at a hundred and fifty military stations, the results of which he had reported to the Secretary of War, and his report had been communicated with that of the Secretary, accompanying the President's message; and he showed me 90 engraved maps on which were marked the direction of all of the storms at the several stations of observation, all confirmative of his theory." Matthew Fontaine Maury (1806–73), assigned in charge of the Depot of Charts, U.S.N., on July 1, 1842, reverted to the subject of ocean currents, in which Benjamin Franklin had achieved both scientific and practical results. Maury's work in collecting half a million observations of winds and currents from the logs of ships and summarizing them for the benefit of mariners fell, opportunely, in the clipper-ship period, and brought him numerous medals, orders of nobility, and a $5,000 service of silver. His Physical Georgraphy of the Sea went through 30 editions in half a dozen languages. He brought about the international conference on maritime meteorology at Brussels in 1853.

Means of rapid communication, lacking when Espy appeared before Congress in 1842, were provided by Morse and Vail in 1844. By 1846, the telegraph net had spread so far that Redfield pointed out that it was now practicable to give warning by telegraph of the approach of West Indian hurricanes. (Am.J.Sci. 2d ser., vol. 2., 1846, p. 334.)

Joseph Henry, who had been in close touch with the meteorological work at Philadelphia from his nearby post at Princeton, became secretary and director of the Smithsonian Institution when it was founded in 1846. An important place in his program was found for meteorological work, and he enlisted the aid of Espy and Loomis in persuading the regents to his point of view. A corps of 150 observers, incorporating Espy's correspondents was equipped and began observing in 1849. Eventually these were increased to over 500. Telegraphic observations were talked of from the first, but were not actually collected until 1857. Experiments were then made in weather forecasting (Henry, J., "Application of telegraph to prediction of changes of weather" Proc. Am. Ac. of Arts and Sci. 4, 1857–60, 271–275). Meantime, in 1855, Leverrier took advantage of the need demonstrated by the loss of the supply fleet of the Allies in the Crimean War in a great storm in the Black Sea, to procure from the Emperor of the French means sufficient for a magnificent weather service that began operations on February 17, 1855, extended over Europe in 1857, and published daily weather charts, beginning September 10, 1863.

Henry renewed his demonstrations of weather telegraphy in 1861 and 1862, but in spite of the great need for weather information in the movement of armies and planning of battles, was not able to get support for the service that he proposed. When Leverrier's maps began to arrive, and news came of the creation of weather forecasting services in every European country, including Turkey, Henry redoubled the fervor of his appeals, but neither the six influential members of Congress on the board of regents of the Smithsonian Institution, nor any other legislator would place his recommendations before Congress.

The present United States Weather Bureau was created by legislation put through Congress by Gen. Halbert E. Paine, Representative from the Milwaukee district, and signed by the President on February 9, 1870, Congressional documents show that Paine was stimulated to this action by a petition written by Increase A. Lapham, a naturalist living in Milwaukee, Wis. This petition recited statistics of marine disasters on the Great Lakes, and pointed to the feasibility of storm warnings on the basis of Espy's findings, and the experience of Leverrier in France. Paine was peculiarly susceptible to this appeal inasmuch as he had been one of Loomis's students at Western Reserve College 25 years before. Lapham had been observer for both Espy and Henry, and was stirred to action at this time by the success of Cleveland Abbe, who demonstrated weather mapping at Cincinnati with the aid of local newspapers and the Western Union Telegraph Co., in a trial beginning September 1, 1869.

The work of building up the new meteorological organization fell upon Chief Signal Officer Albert J. Myer, formerly an Army surgeon, who had invented the now-familiar wigwag signals with flags and torches to replace couriers as a means of military communication. Myer undertook the new work with unbounded energy and ambition. He trained observers, arranged telegraph circuits, equipped stations, and began operations within 9 months after the enactment of the Paine bill. The success of the work was immediate. Within 2 years the demands of the public had added "prediction of the weather for the benefit of commerce and agriculture", the gaging of rivers and the forecasting of floods. The collection of marine intelligence, which had fallen into abeyance after Maury threw in his lot with the Confederacy, was revived by General Myer. The financial panic of 1873 tied up the funds of the Smithsonian Institution, then in a private bank, and compelled Henry to offer the Smithsonian meteorological system to Myer. The transfer occurred in 1874, and included the meteorological work of the Medical Department of the Army. In addition to these routine duties, Myer, as member of the International Congress of Meteorology at Vienna in 1873, persuaded the representatives of other nations to join in international simultaneous observations, the mapping and publication of which fell to the United States. Abbe calls this "the finest piece of international cooperation in scientific work that the world has ever seen."

In June 1871 Myer took over the mountain observatory that had been established on Mount Washington by Hitchcock, of the New Hampshire Geological Survey, 6 months earlier. In 1873 observatories were set up on Mount Mitchell, N.C., and Pikes Peak, Colo. The first and last of these mountain observatories were continued for many years, and contributed valuable information about the meteorology of the upper air. Myer also cooperated with several polar explorers by detailing trained meteorologists to accompany them.

Pioneers in dynamical meteorology.—No mathematics more advanced than arithmetic was invoked in the theoretical meteorology of Halley, Hadley, Dove, Redfield, Espy, and Loomis, nor in the applied meteorology of Leverrier and Myer. This is the more remarkable inasmuch as the science of mechanics, founded in the sixteenth and seventeenth centuries by Galileo (1546–1642), Kepler (1571–1630), and Newton (1642–1727), had been brought to perfection as a mathematical science by Euler (1707–83), d'Alembert (1717–83), Lagrange (1736–1813), and Laplace (1749–1827) in the eighteenth century.

The relation of wind to pressure, and the deflective effect of the earth's rotation were expressed in their final analytical form as early as 1835 by G. G. Coriolis (1792–1843) director of studies in the École Polytechnique, one

of the two French government schools (the other being the École Normale Supérieure) which lead the world in mathematical physics. (Coriolis, "Sur la manière d'établir les différens principes de mécanique pour des systèmes de corps en les considérant comme des assemblages de molécules" Paris, J. École Poly., 15, 1835, 93–125 and "Sur les équations du mouvement relatif des systèmes de corps," same p. 142–154) Poisson applied the theory of the deflective effect of the earth's rotation to the motion of projectiles in the very year (1837) that Loomis attended his lectures, that is to say, at the moment when this principle if known, would have resolved the difference between Redfield and Espy and anticipated Ferrel by 20 years.

The circulation of the atmosphere as a whole, first considered by Halley in 1686, and more adequately by Hadley in 1735, lay untouched until Maury's "Wind and current charts" brought him face to face with the same problem. His model of the winds aloft, although supported by authorities ranging from the Hebrew prophets to Faraday's recent discovery of the paramagnetism of oxygen, was unsatisfactory to a Nashville, Tenn. high-school principal, whose hobby was celestial mechanics and hydrodynamics. This was William Ferrel (1817–91) whose first paper on the subject, a nonmathematical outline of his theory, appeared in the Nashville Journal of Medicine and Surgery, October-November 1856. In the following year, Ferrel joined the staff of the Nautical Alamanac Office, at Cambridge, Mass., and there worked up his ideas and reasoning into a mathematical paper which was published in Runkle's Mathematical Monthly, vols. 1 and 2, 1858 and 1859, and in simplified form in the American Journal of Science, 1860.

Ferrel's model of the general circulation of the atmosphere was necessarily based on few observations in the Arctic and none in the Antarctic, and was subsequently changed by himself in 1860 and 1889. The 1889 model differed inappreciably from the circulation proposed, without mathematical analysis, by James Thomson, brother of Lord Kelvin, before the British association in 1857. However, Ferrel's earlier intuition proves to be more in accord with the working picture formed by Hildebrandsson and de Bort from more complete collections of data. (Hobbs, Glacial Anticyclones, 1926, p. 19.)

Ferrel's great contribution to meteorology was the discovery and mathematical formulation of the laws of motion of the atmosphere on a rotating globe. Following his pioneer effort, Sprung, Guldberg and Mohn, Helmholtz, Margules, Siemens, Oberbeck, and Rayleigh have worked to improve and extend the subject. Ferrel's mathematical style has been criticised as lacking finish, but Marcel Brillouin, of the École Normale Supérieure, who reproduced Ferrel's papers in his "Mémoires originaux sur la circulation générale de l'atmosphère" says in his introduction, p. vii, "one cannot sufficiently admire this collection of Ferrel's memoirs; in the rigor of reasoning as well as in the subtlety of ideas, the student of Nashville is a worthy predecessor of von Helmholtz."

Sir Napier Shaw points out that meteorological theory has been invariably hampered by want of facts. All the work on dynamical meteorology before Helmholtz he regards as "interesting speculations about a planet which does not represent the earth as we know it, nor can the application to the real earth be developed by any slight modification of the hypothesis." Helmholtz, however, "opens out a new province by using his reasoning to develop certain processes which are operative in any part of the atmosphere in accordance with the laws of dynamics and reaches conclusions which one may expect to find illustrated wherever the atmosphere admits the prescribed assumptions." The chief problem of meteorology today is the discovery of the facts, and the adaptation of theory to them in detail. Shaw names Buys Ballot, Buchan, de Tastes, and Duclaux, Hildebrandsson, Teisserenc de Bort, Hann, and Koeppen, as representatives of this inductive school of theoretical meteorologists. To these we may add Shaw himself, and the Bjerkneses, father and son. Among Americans, Frank H. Bigelow's prodigious labors on the "International Cloud Observations", "The Barometry Report", and a long series of papers on the general circulation of the atmosphere in the Monthly Weather Review, 1902–6, fall into this class.

Among signs that meteorology is approaching the standard set by astronomy, the "precision of which in predicting the positions of the heavenly bodies is the admiration and the envy of all other sciences" (Shaw, Man. of Mety., pt. 1, p. 316) are the graphical calculus of atmospheric motions of V. Bjerknes (Dynamic Meteorology and Hydrography, 1911) and the most explicit example of quantitative forecasting, of Richardson (Weather Prediction by Numerical Process, Cambridge, England, 1922). The latter scheme is designed to forecast the weather of the whole world, and the author estimates the number of computers required to "race the weather" at the staggering number of 64,000. It is therefore obvious that further pioneering as well as improvement in economic and political conditions is necessary before the qualitative meteorology handed down to us by Redfield, Espy, and Loomis can be superseded by the quantitative meteorology of Helmholtz, Bjerknes, and Richardson.

A BRIEF LIST OF WORKS ON METEOROLOGY

Compiled by C. F. TALMAN

GENERAL TREATISES

Angot. Alfred. Traité élémentaire de météorologie. 4th ed. Paris. 1928.
Boy scouts of America. Weather. New York. 1928. (Merit badge series 3816). (By W. J. Humphreys and C. F. Talman).
Brunt, David. Meteorology. London. 1928.
Davis, William Morris. Elementary meteorology. Boston. 1894.
Geddes, A. E. M. Meteorology; an introductory treatise. London, 1921.
Great Britain, Meteorological office. The Weather map; an introduction to modern meteorology. 2d ed. London. 1930.
Great Britain, Meteorological office. Meteorological glossary. 2d ed. London. 1930.
Greely, Adolphus W. American weather. New York. 1888.
Hann, J. von, & Süring, R. Lehrbuch der Meteorologie. 4th ed. Leipzig. 1926.
Humphreys, William J. Physics of the air. 2d ed. New York. 1929.
Linke, Franz, ed. Meteorologisches Taschenbuch. 2 vols. Leipzig. 1931–1933.
Milham, Willis I. Meteorology. New York. 1912.
National research council. Physics of the earth. 3. Meteorology. Washington. 1931.
Pick, W. H. A short course in elementary meteorology. 3d ed. London. 1930. (Great Britain, Meteorological office. M.O. 247).
Shaw, Sir Napier. Manual of meteorology. 4 vols. Cambridge. 1926–1931.
Talman, Charles Fitzhugh. The realm of the air. Indianapolis. 1931.
Waldo, Frank. Elementary meteorology. New York. 1896.

WEATHER AND WEATHER FORECASTING

Bliss, George S. Weather forecasting. 5th ed. Washington. 1929. (U.S. Weather Bureau. Bull. 42).
Brooks, Charles F. Why the weather? New York. 1924.
Brooks, C. E. P. The weather. London. 1927.
Chapman, E. H. The study of weather. Cambridge. 1919.
Defant, Albert. Wetter und Wettervorhersage. 2d ed. Leipzig. 1926.
Georgii, Walter. Wettervorhersage; die Fortschritte der synoptischen Meteorologie. Dresden. 1924.
Humphreys, William J. Rain making and other weather vagaries. Baltimore. 1926.
Humphreys, W. J. Weather proverbs and paradoxes. Baltimore. 1923.
Inwards, Richard. Weather lore; a collection of proverbs, sayings, and rules concerning the weather. 3d ed. London. 1898.
Kassner, Carl. Das Wetter und seine Bedeutung für das praktische Leben. 2d ed. Leipzig. 1918.
Shaw, Sir Napier. Forecasting weather. 2d ed. London. 1923.
U.S. Weather Bureau. Weather forecasting in the United States. Washington. 1916.

DYNAMIC METEOROLOGY

Abbe, Cleveland. The mechanics of the earth's atmosphere. A collection of translations (2d collection). Washington. 1891. Third collection. Washington. 1910. (Published by Smithsonian institution.)
Exner, Felix M. Dynamische Meteorologie. 2d ed. Wien. 1925.
Ferrel, William. A popular treatise on the winds. New York. 1889.
Ferrel, William. Recent advances in meteorology. Washington. 1886. (Annual report of the chief signal officer, 1885. Appendix 71.)
Lempfert, Rudolph G. K. Meteorology. London. 1920.

STORMS

Algué, José. Cyclones of the far east. 2d ed. Manila. 1904.
Bowie, Edward H., & Weightman, R. Hanson. Types of storms of the United States and their average movements. Washington. 1914. (U.S. Weather Bureau. Monthly weather review. Supplement 1.)
Cline, Isaac M. Tropical cyclones. New York. 1926.
Fassig, Oliver L. Hurricanes of the West Indies. Washington. 1913. (U.S. Weather Bureau. Bull. X.)
Finley, John P. Tornadoes; what they are and how to observe them. New York. 1887.
Froc, Louis. L'atmosphère en extrême-orient; son état normal, ses perturbations. 2d ed. Paris. 1920. [Full account of typhoons.]
Garriott, E. B. West Indian hurricanes. Washington. 1900. (U.S. Weather bureau. Bull. H.)
Laughton, L. G. C., & Heddon, V. Great storms. London. 1927.
Mitchell, Charles L. West Indian hurricanes and other tropical cyclones of the North Atlantic Ocean. Washington. 1924. (U.S. Weather bureau. Monthly weather review. Supplement 24.)
Newnham, E. V. Hurricanes and tropical revolving storms. London. 1922. (Great Britain, Meteorological office. Geophysical memoirs no. 19.)
Visher, Stephen S. Tropical cyclones of the Pacific. Honolulu. 1925. (Bernice P. Bishop museum. Bull. 20.)
Wegner, Alfred L. Wind- und Wasserhosen in Europa. Braunschweig. 1917.

FROST

Young, Floyd D. Frost and the prevention of frost damage. Washington. 1929. (U.S. Dept. of agriculture. Farmers' bull. 1588.)
Reed, William Gardner. Frost and the growing season. Washington. 1918. (U.S. Dept. of agriculture. Atlas of American agriculture, part 2, sect. 1.)

CLOUDS

Clarke, George A. Clouds. London. 1920.
Clayden, Arthur William. Cloud studies. 2d ed. London. 1925.
Great Britain, Meteorological office. Cloud forms according to the international classification. 2d ed. London. 1921.
Humphreys, William J. Fogs and clouds. Baltimore. 1926.
International meteorological committee. International atlas of clouds and of states of the sky. Abridged ed. Paris. 1930. Complete ed. Paris. 1933.
U.S. Weather bureau. Cloud forms according to the international system of classification. 2d ed. Washington. 1928.

ATMOSPHERIC ELECTRICITY

Chauveau, B. Electricité atmosphérique. Paris. 1922–25.
Covert, Roy N. Protection of buildings and farm property from lightning. Washington. 2d ed. 1930. (U.S. Dept. of agriculture. Farmers' bull. 1512.)
Gockel, Albert. Das Gewitter. 3d ed. Berlin. 1925.
Kähler, Karl. Einführung in die atmosphärische Elektrizität. Berlin. 1929.
Peters, Orville S. Protection of life and property against lightning. Washington. 1915. (U.S. Bureau of standards. Technologic paper 56.)
Schonland, B. F. J. Atmospheric electricity. London. 1932.
Swann, W. F. G. Atmospheric electricity. (In Journal of Franklin institute, Philadelphia, Nov. 1919, pp. 577–606.)
U.S. Bureau of standards. Code for protection against lightning. Washington. 1929.
Voigts, Heinrich. Luftelektrizität. Berlin. 1927.

METEOROLOGICAL OPTICS

Pernter, Joseph M., & Exner, Felix M. Meteorologische Optik. 2d ed. Wien, etc. 1922.

INSTRUMENTS, INSTRUCTIONS, TABLES

Great Britain, Meteorological office. The computer's handbook. London. 1915–. [In course of publication, in parts.]
Great Britain, Meteorological office. The meteorological observer' handbook. London. 1926.
Smithsonian institution. Smithsonian meteorological tables. 5th ed. Washington. 1931.
U.S. Weather bureau. Circulars. A. Instructions for obtaining and tabulating records from recording instruments. B. and C., combined, Instructions for coöperative observers. D. Instructions for the installation and maintenance of wind measuring and recording apparatus. E. Measurement of precipitation. F. Barometers and the measurement of atmospheric pressure. G. Care and management of electrical sunshine recorders. I. Instructions for erecting and using weather bureau nephoscope.

L. Instructions for the installation and operation of class A evaporation stations. M. Instructions to marine meteorological observers. N. Instructions for airway observers. O. Instructions for making pilot balloon observations. P. Instructions for making aerological observations. Q. Pyrheliometers and pyrheliometric observations. Washington. [Various dates.]
U.S. Weather bureau. Psychrometric tables. Washington. 1912.

AGRICULTURAL METEOROLOGY

Henry, A. J., & others. Weather and agriculture. Washington. 1925. (U.S. Dept. of agriculture. Separate from yearbook, 1924. No. 918.)
Holdefleiss, Paul. Agrarmeteorologie. Berlin. 1930.
Smith, J. Warren. Agricultural meteorology. New York. 1920.

MARINE METEOROLOGY

Allingham, William. A manual of marine meteorology. 3d ed. London. 1927.
Great Britain, Meteorological office. The seaman's handbook of meteorology. 3d ed. London. 1918.
Great Britain, Meteorological office. A barometer manual for the use of seamen; a text book of marine meteorology. 11th ed. London. 1932.
Smith, L. A. Brooke. Wireless and weather; an aid to navigation. London. 1928. (Great Britain, Meteorological office, M.O. 297.)
U.S. Weather bureau. Instructions to marine meteorological observers. 5th ed. Washington. 1929. (Circular M.)

AERONAUTICAL METEOROLOGY

Baldit, A. Les routes aériennes de l'Atlantique. Paris. 1928.
Georgii, Walter. Flugmeteorologie. Leipzig. 1927.
Gregg, Willis R. Aeronautical meteorology. 2d ed. New York, 1930.
Maguire, Charles Joseph. Aerology. A ground school manual in aeronautical meteorology. New York. 1931.
Noth, Hermann. Wetterkunde für Flieger. Berlin. 1932.

CLIMATOLOGY

Bonacina, L. C. W. Climatic control. 3d ed. London. 1927.
Brooks, C. E. P. The evolution of climate. 2d ed. London, 1925.
Edwards, K. C. The A B C of climate. London. [1930.]
Hann, Julius. Handbuch der Klimatologie. 3d ed. Stuttgart. 1908–11. v. 1, 4th ed. 1932. 3 vols. [The second edition of the first volume has been translated into English, with some additions, by R. DeC. Ward, New York, 1903, but the translation is out of print and rare.]
Kendrew, W. G. Climate. Oxford. 1930.
Köppen, W. Grundriss der Klimakunde. Berlin. 1931.
Miller, A. A. Climatology. London. 1931.
Ward Robert DeCourcy. Climate, considered especially in relation to man. 2d ed. New York. 1918.
Weber, F. Parkes, & Hinsdale, Guy. Climatology; health resorts; mineral springs. Philadelphia. 1902. 2 vols. (Cohen, S. S. A system of physiologic therapeutics, vols. 3 and 4.)

CLIMATOGRAPHY

Brooks, C. E. P. Climate. 2d ed. London. 1932.
Kendrew, W. G. Climates of the continents. 2d ed. Oxford. 1927.
Köppen, W., & Geiger, R., eds. Handbuch der Klimatologie. 5 vols. Berlin. 1930–. [In course of publication, in parts.]

The only other comprehensive descriptive work on the climates of all parts of the world, with tabulated statistics and references to all the important literature of climatography, is J. Hann's Handbuch der Klimatologie, 3d ed., Stuttgart, 1908–11. Vols. 2 and 3, dealing with climatography, have not been translated.

The leading collection of climatic charts for the whole world is J. G. Bartholomew's Atlas of meteorology, Westminister, 1899 (Bartholomew's physical atlas, vol. 3).

Records of barometric pressure, temperature, and precipitation for 387 selected stations in different parts of the world are given in H. Helm Clayton & others, World weather records. Washington. 1927. (Smithsonian miscellaneous collections, vol. 79.)

On the climate of the United States consult Alfred J. Henry, Climatology of the United States, Washington, 1906 (U.S. Weather bureau. Bull. Q); Robert DeC. Ward, Climates of the United States, Boston, 1925; and U.S. Dept. of agriculture, Atlas of American agriculture, pt. 2, Climate, Washington, 1918–28.

The chief collection of rainfall data for the world at large, exclusive of Europe, is Alexander Supan's Verteilung des Niederschlags auf der festen Erdoberfläche, Gotha, 1898. (Petermann's Mitteilungen, Ergänzungsheft 124).

There is a voluminous literature on regional and local climatography.

LEADING METEOROLOGICAL JOURNALS

Annalen der Hydrographie und maritimen Meteorologie. Berlin, etc. 1873–.
Beiträge zur Physik der freien Atmosphäre. Strassburg. 1904–.
Bulletin of the American meteorological society. Worcester, Mass. 1920–.
Marine observer. London. 1924–. [Published by Meteorological office.]
Meteorological magazine. London. 1866–. [Published by Meteorological office.]
Météorologie. Paris. 1925–. [Published by Société météorologique de France.]
Meteorologische Zeitschrift. Braunschweig, etc. 1884–.
Monthly weather review. Washington. 1872.– [Published by U.S. Weather bureau.]
Quarterly journal of the Royal meteorological society. London. 1871–.
Zeitschrift für angewandte Meteorologie. Berlin. 1885–.

WEATHER TYPES AND PRESSURE ANOMALIES [1]

By THOMAS A. BLAIR

[Weather Bureau, Lincoln, Nebr., June 21, 1933]

INTRODUCTION

Students of weather phenomena in temperate latitudes are familiar with the fact that similar weather conditions, cyclones and anticyclones of like characteristics and paths frequently follow one another in succession for a fortnight, or a month or longer, and then quickly give way to weather of quite a different character. These persistences of indefinite duration commonly called, "weather types", are spoken of by Kendrew (**1**) as "weather units of the second order."

Familiar examples of such weather persistences are the cold winters and the warm winters of central and eastern United States and Canada; the wet and the dry winters of California; and the occasional prolonged droughts in the eastern half of the United States, such as occurred in the summer of 1930. These are illustrations of the persistence of type for several months, and Henry (**2**) remarks that "a single type of cyclonic movement occasionally dominates the weather for 2 months in winter and marked temperature anomalies may continue for 3 or 4 months." This continuance for several months is also shown by such sequence relationships between one month and the following month or months as have been found by Reed (**3**) at Des Moines and by Weeks (**4**) at Baltimore. But such correlations are never perfect and the type frequently changes abruptly in the midst of a season.

Similar conditions obtain in temperate South America. Hessling (**5**), speaking of Argentina, says that the forecaster "is struck by the remarkable tendency of certain types of pressure distribution and weather to repeat themselves in some years or seasons, while in other years the opposite types are more frequent." On the other hand, while such types are a prominent feature of the weather of the British Isles and central Europe, their duration there is commonly much shorter. Kendrew (**1**) says of England, "The spell lasts perhaps for a fortnight, then suddenly the sequence is broken and a different type of weather sets in."

It is generally agreed that this sort of variability of the weather is connected with alterations in the general circulation, and it is customary to say that such alterations result in changes in the position and intensity of the seasonal, semipermanent, centers of high and low pressure and consequent changes in the paths and frequency of traveling cyclones and anticyclones. But there is less agreement as to the way in which modifications in the general circulation are brought about.

There are at least three lines of thought in this connection. First, there is much evidence of the existence of waves or oscillations in the atmosphere, resulting in correlations between weather elements in distant parts of the world, either contemporaneously or with succeeding seasons. In connection with these correlations A. Wagner (**6**) emphasizes the importance of persistence, saying, "The value of these correlation factors for forecasting purposes appears to rest solely on the fact that the general circulation shows a considerable tendency to maintain its condition." Another group of students finds latitudinal displacements of the pressure belts and ascribes such movements to variations in the intensity of solar radiation. A third explanation of the variability of seasons is found in the movement and continued separate existence of air masses, as developed since the announcement of the Bjerknes polar front theory.

Observational data are inadequate to permit a physical analysis of the observed changes or completely to confirm or refute any one of these explanations. There appears no reason why all three of the processes may not be simultaneously at work producing the existing complex situation at any moment.

The accompanying short series of maps illustrates one method of representing changes in the general circulation with particular reference to its tendency to maintain its condition. It is thought that they give some indication of the natural processes which result in the persistence of weather types. Perhaps they are most intelligible in terms of displacements of air masses. In this view the maps may be considered as illustrations of the never-ending conflict between the prevailing westerlies and the cold currents blowing out of the polar anticyclones.

The maps show mean pressure departures in millibars in the Northern Hemisphere in successive, overlapping, 3-month periods from the autumn of 1913 to the summer of 1914. They are based on data for only 48 stations and, accordingly, can do no more than indicate roughly the major pressure conditions. They are chiefly of interest with reference to that region in which seasonal variability is of the greatest practical import, that is, in middle temperate portions of the Northern Hemisphere, in which the world's population is largely concentrated.

DISCUSSION OF THE MAPS

Figure 1, September-November.—Beginning with the autumn months of 1913, we find that pressure is deficient throughout polar regions but that more than the normal mass of air has accumulated in middle and lower latitudes, especially in eastern America and the western Atlantic. Does this deficiency of dense air in polar regions point toward a winter warmer than normal in middle latitudes?

Figure 2, October-December.—Dropping September and adding December, we find the deficiency has increased in intensity but is being closely pressed by wedges of high pressure over the continents, in Siberia, Europe, and eastern North America. Evidently the type of weather we have here is that of frequent cyclones taking the northern route across both continents. The British Isles are on the dividing line and subject to frequent changes of type.

Figure 3, November-January.—The deficit continues to become greater in polar regions and now shows a tendency to separate into three distinct centers, over Alaska, Iceland, and Russia, respectively. Both the Alaskan and Russian centers have moved slowly eastward as compared with the previous map, and the Siberian excess has spread eastward into the middle Pacific region. As winter develops the type of weather certainly remains the same for Asia. In Great Britain and the southern half of Europe the weather is influenced by the excess pressure from Ireland to Portugal, and the January temperature at Milan was 2.5° F. below normal. In North America note the northward bending of the lines in the center of the con-

[1] Read at the meeting of the American Meterorological Society, Chicago, June 19–21, 1933.

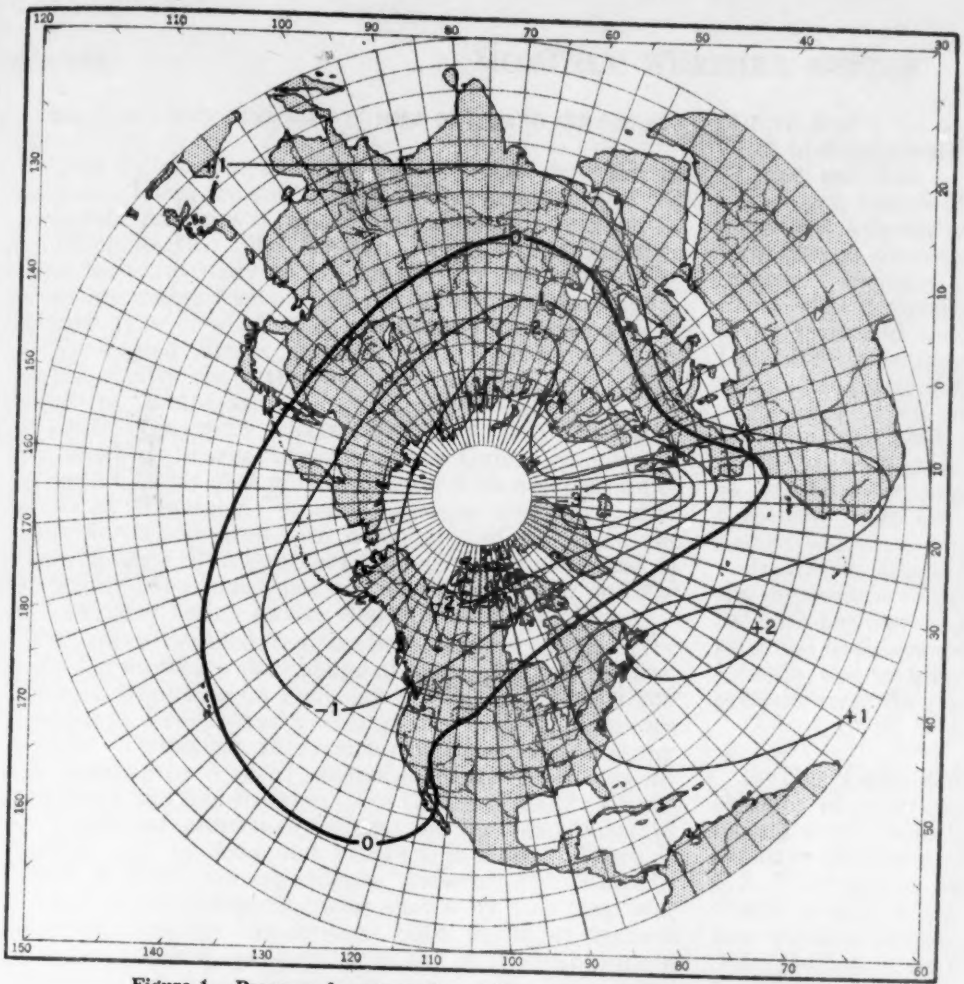


Figure 1.—Pressure departures in millibars, September–November 1913.

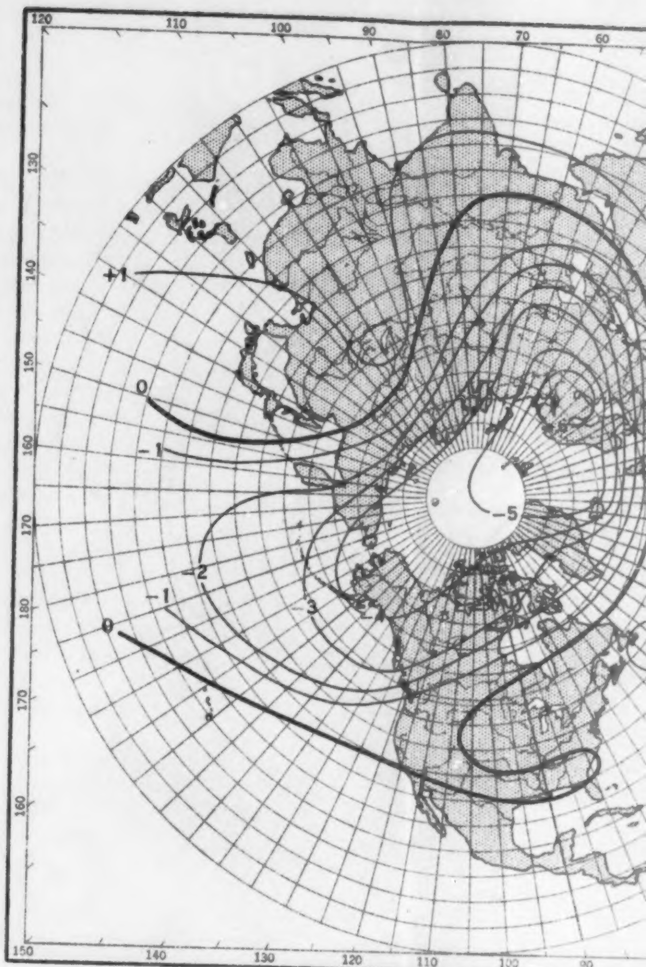


Figure 2.—Pressure departures in millibars, October–

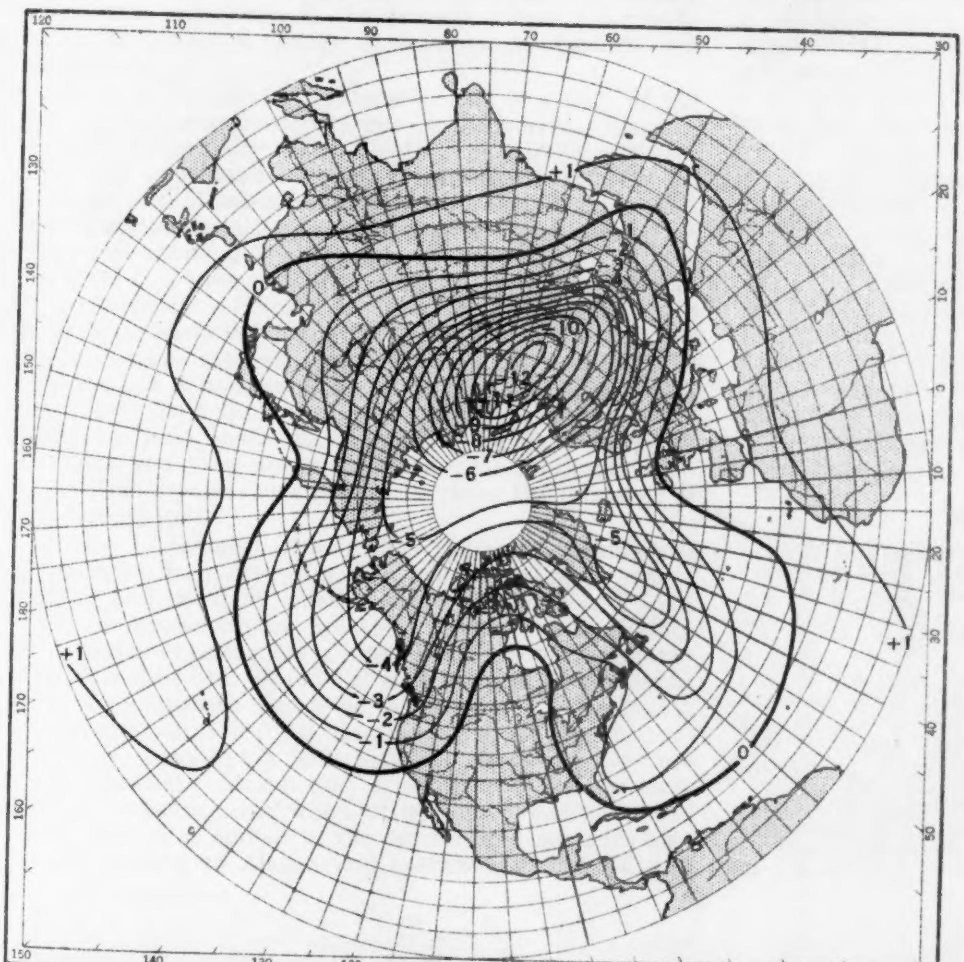


Figure 4.—Pressure departures in millibars, December 1913–February 1914.

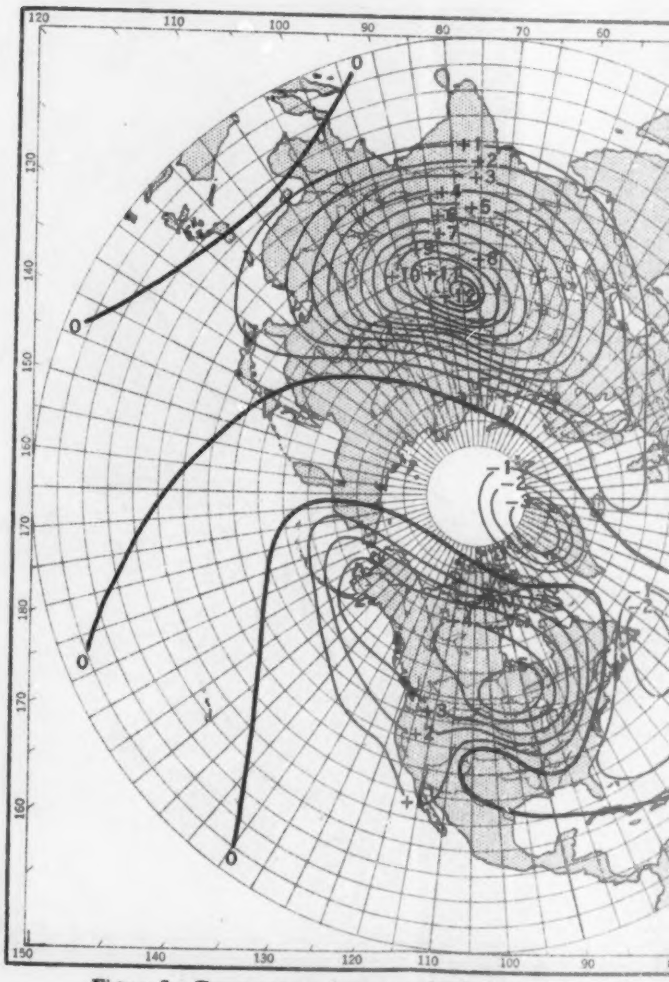
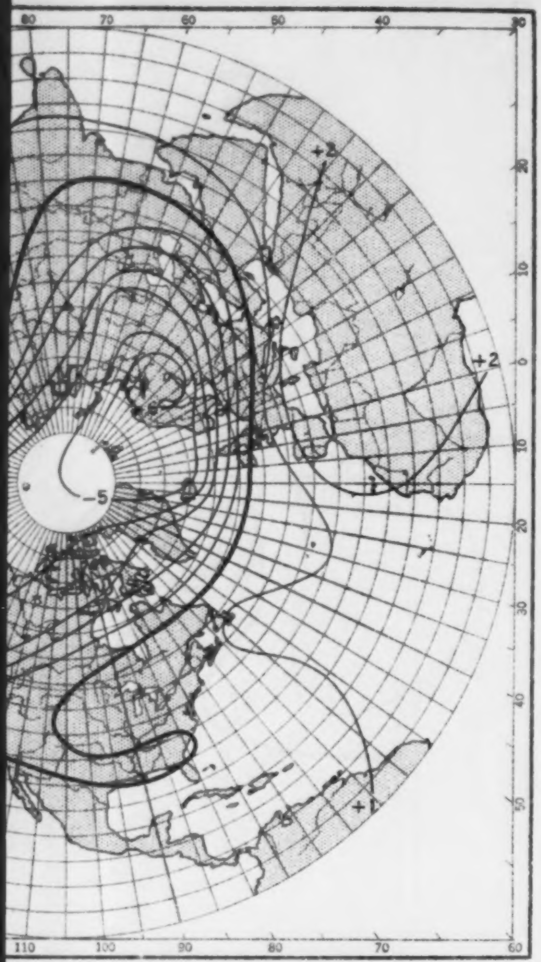


Figure 5.—Temperature departures in degrees F., December 1



res in millibars, October–December 1913.

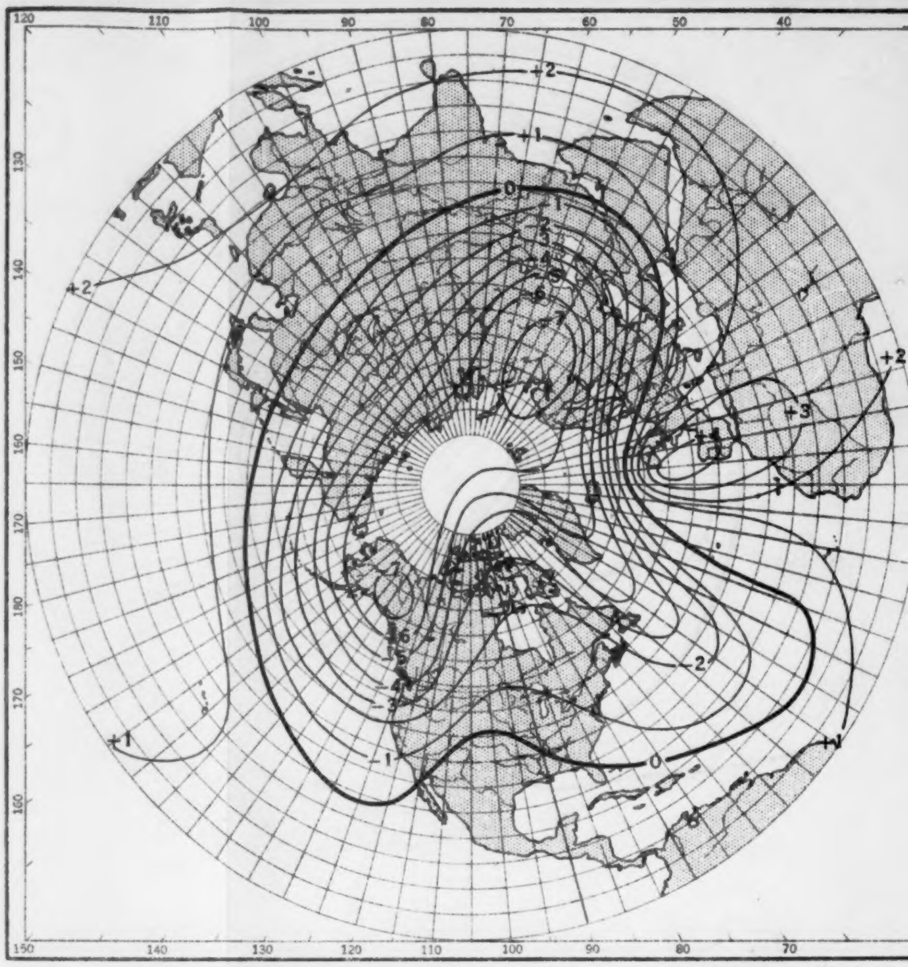
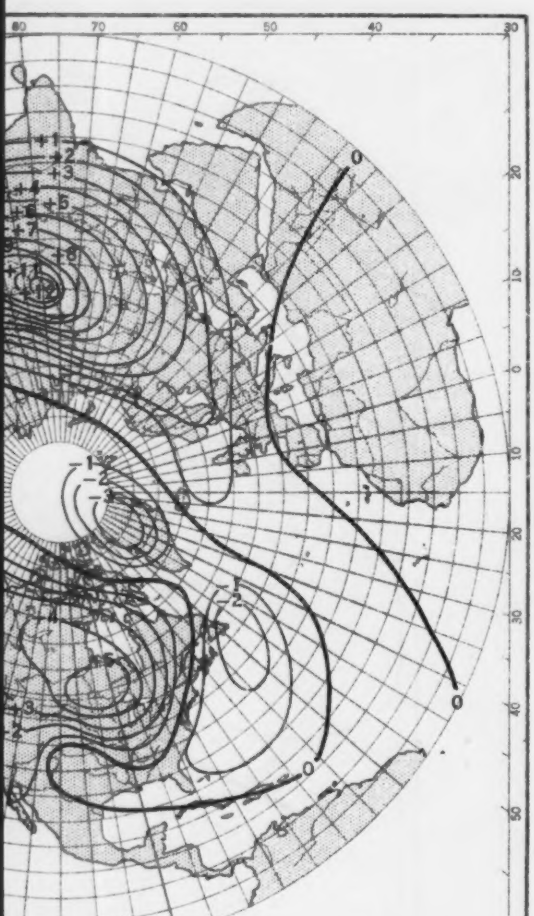


Figure 3.—Pressure departures in millibars, November 1913–January 1914.



s in degrees F., December 1913–February 1914.

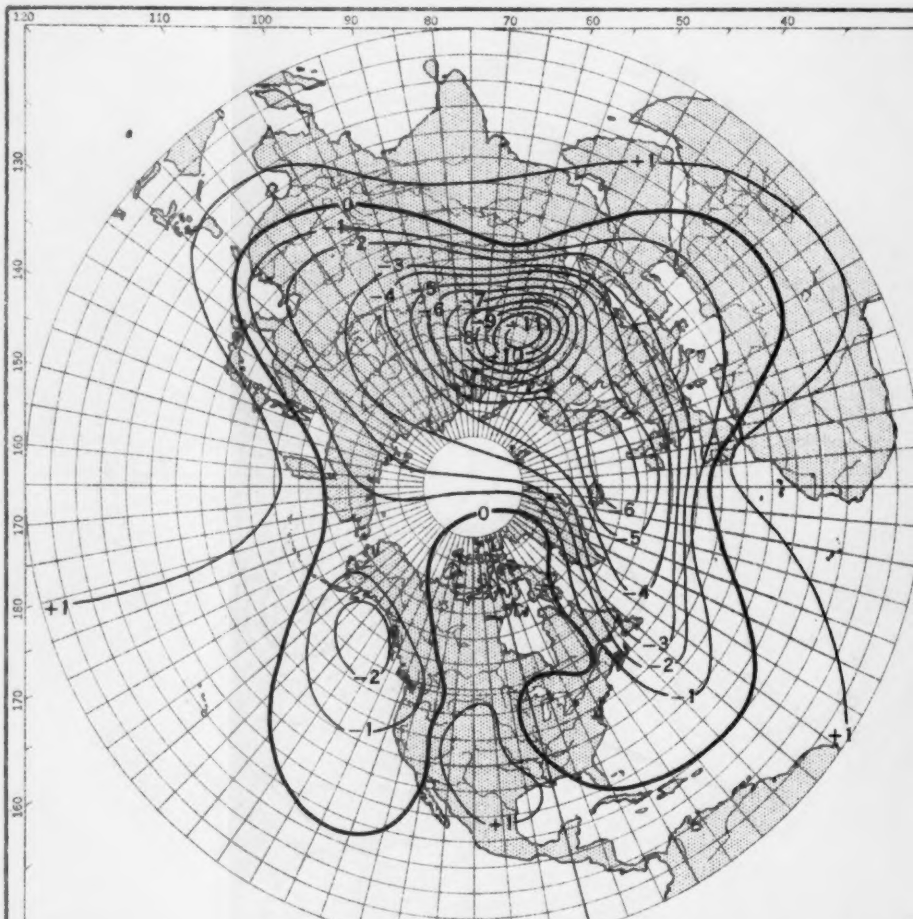


Figure 6.—Pressure departures in millibars, January–March 1914.

1914.

LXI—73

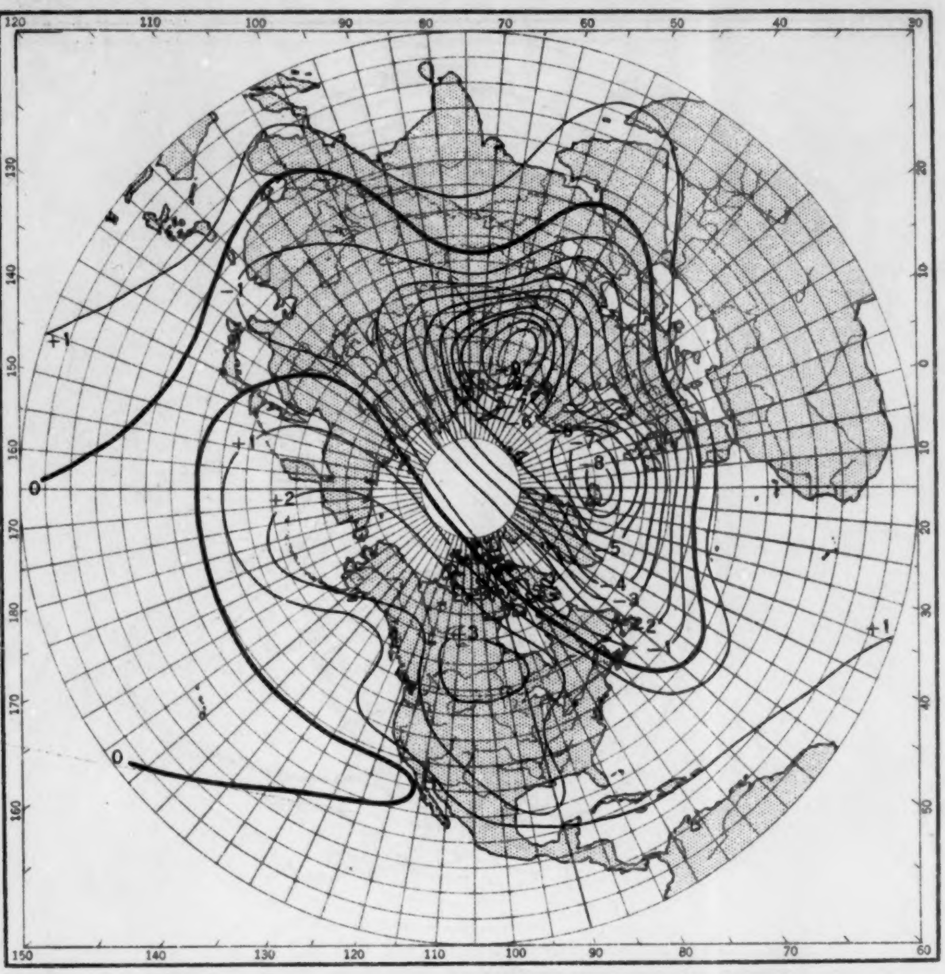


Figure 7.—Pressure departures in millibars, February–April 1914.

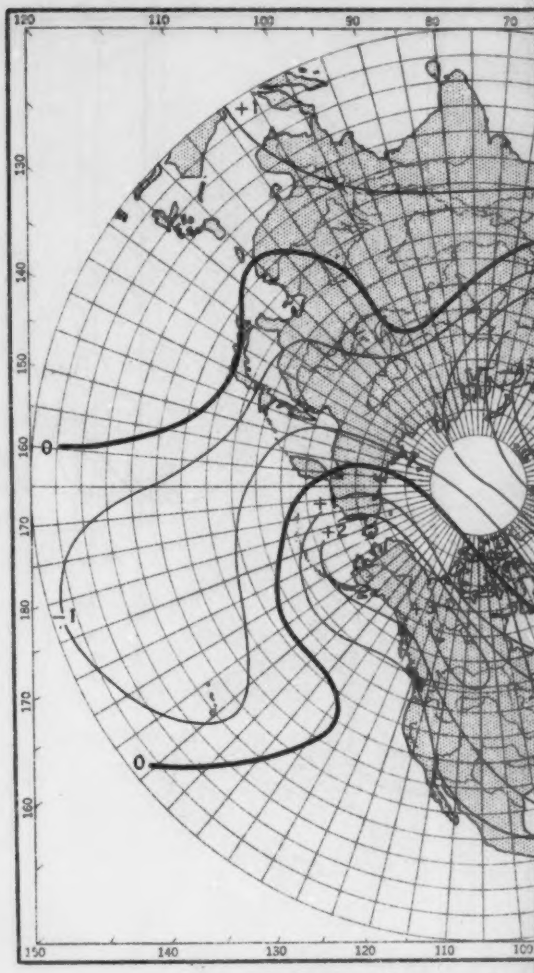


Figure 8.—Pressure departures in mi

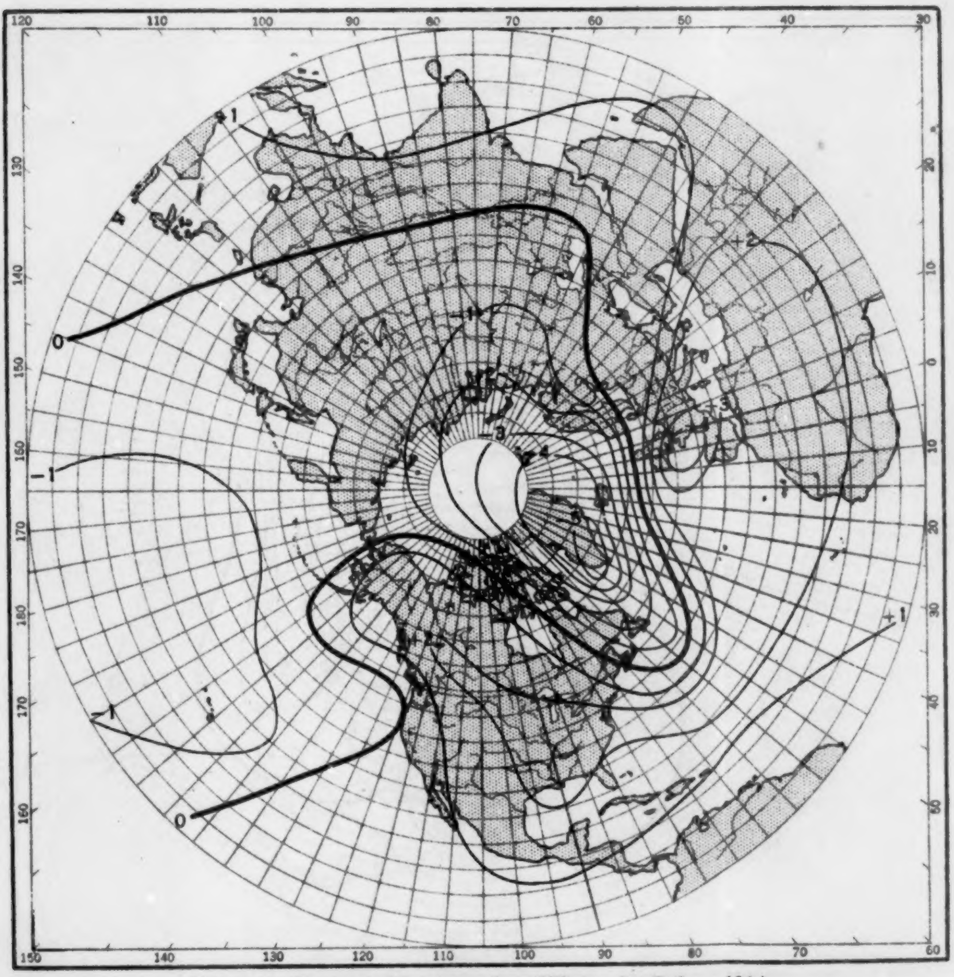


Figure 9.—Pressure departures in millibars, April–June 1914.

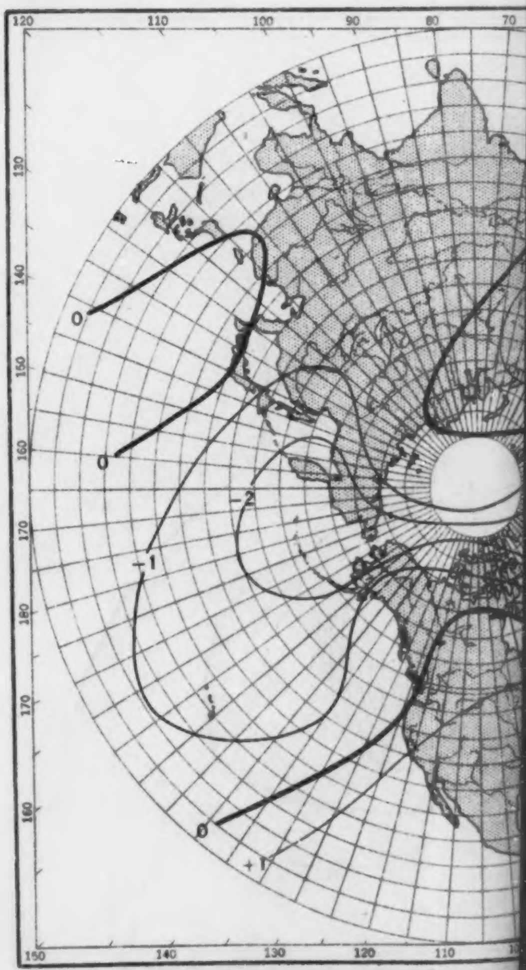


Figure 10.—Pressure departures in

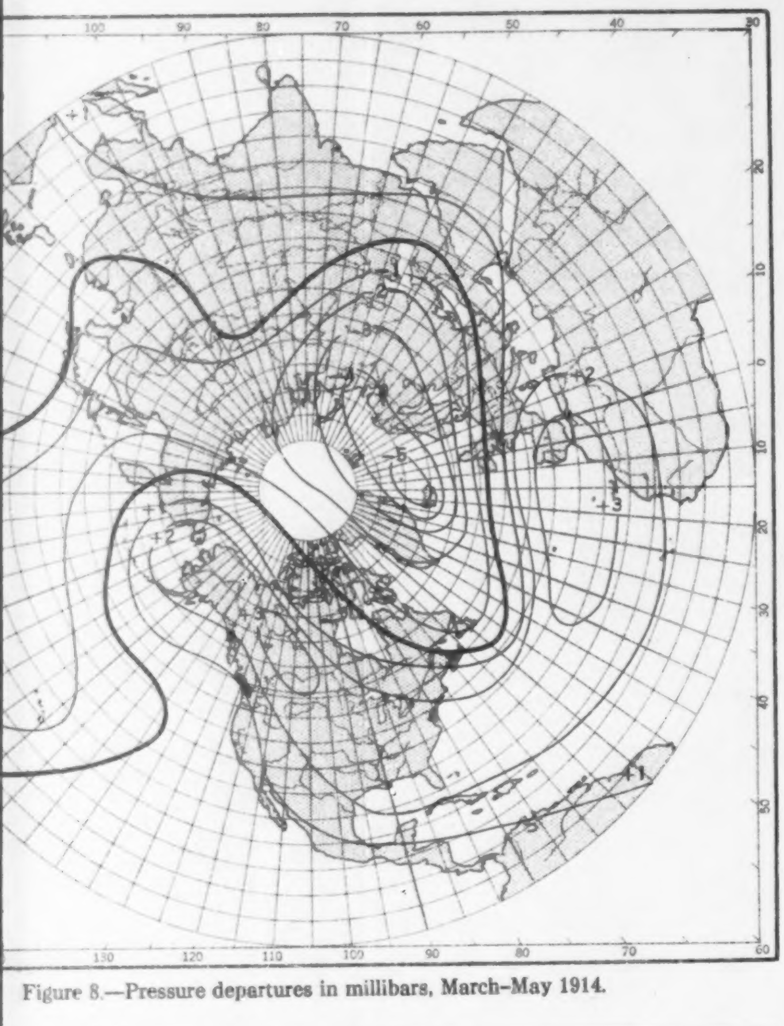


Figure 8.—Pressure departures in millibars, March–May 1914.

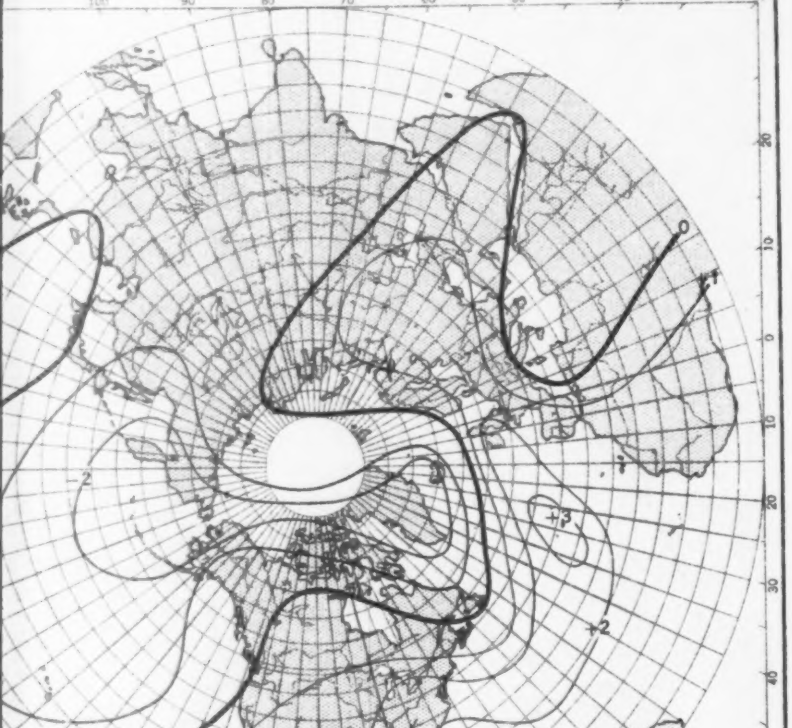


Figure 10.—Pressure departures in millibars, May–July 1914.

tinent, which may portend a change of type in the eastern half.

Figure 4, December-February.—Here are the three winter months. There are still wedges of high pressure over the continents and now a fourth has appeared over Japan and Kamchatka. The Russian center of low pressure continues to intensify and to drift slowly eastward. The American wedge has pushed northward and brought a different type of weather to central and eastern portions of the United States and Canada. The temperature records clearly show this abrupt change of type. The charts of temperature departures published in the MONTHLY WEATHER REVIEW **(7)** show that December was decidedly warm throughout the United States and southern Canada east of the Rockies, with a departure of 15° F. at Winnipeg. January likewise was warm over nearly the whole area with departures of 12° F. in the Great Plains. But February was decidedly cold east of the Rocky Mountains, parts of the Lake region and the St. Lawrence Valley having departures of −9° F.

The more detailed temperature records **(8)** give the exact day on which the change of type occurred, the first cold spell beginning on February 4th in the Missouri and Mississippi Valleys and reaching the Eastern States on the 7th. Thereafter, the month was almost continuously cold, marked by a rapid succession of surges of cold air from the Canadian interior. On the other hand, February continued abnormally warm on the west coast of America and in Asia and northern Europe. There is clearly a close correspondence between the 3-month average pressure departures as shown by this map and attendant weather conditions, both in those regions showing a marked change in type and in those showing a persistence of type. Evidently such maps have some elements of validity as pictures of atmospheric processes. There was, moreover, in the preceding map some indication that such a change as occurred in America was impending.

Figure 5, Winter temperatures.—This is a map of the average temperature departures for the 3 winter months, showing abnormally warm weather in middle latitudes over the continents, especially southeastward of the Alaskan and Russian centers of deficit, and confirming the significant relation between seasonal pressure departures and seasonal temperature departures.

Figure 6, January-March.—Rising pressure continues over the interior of North America, and the Pacific excess is pressing eastward toward Alaska, where negative departures have decreased considerably. It appears that the Alaskan depression is about to fill up or to be separated from the main area of deficit and pushed southward. If this happens, there will be another change in the paths of highs and lows across America. Great Britain and most of Europe are now distinctly under the influence of the Iceland low.

Figure 7, February-April.—The indicated realinement of pressure in North America has taken place rather rapidly and the daily weather maps of March and April show the accompanying weather changes. The number of cyclones entering the United States from the northwest was 8 in March and fell to 4 in April; the number from the southwest was none in January, 1 in February, 2 in March, and 5 in April, showing a distinct change from northerly to southerly lows with the change of pressure here indicated. March and April on the average have about the same distribution of northerly and southerly types. **(9)**. The spread of the central high pressure area northwestward to Alaska and eastward to the Atlantic is first shown on the daily weather map of March 21. Marked deficits continue over the north Atlantic, northern Europe, and Asia.

Figure 8, March-May.—Positive departures are increasing in the Atlantic and Europe while the adjoining negative area is decreasing both in extent and depth, but increased dficiency is developing in the Pacific. As this Pacific deficit reaches the coast of British Columbia, there is an increased number of northerly lows across the United States during May. The type of weather has again changed in England and central Europe.

Figure 9, April-June.—The changes in process in the previous map continue. The area of excess is moving northward in Europe and Asia and receding from Alaska, as the Pacific negative area moves eastward. For 3 months there has been a continuous filling up of the Asiatic low.

Figure 10, May-July.—Again the changes continue in the same sense and changes of weather type are indicated for both the eastern and western hemispheres. We have returned to subnormal pressure over Alaska and northern Canada, and we have for the first time in this series excess pressure over Russia.

CONCLUSION

1. The maps show that, superposed on the daily changes of pressure, there are units of pressure of a second order, large and persistent areas of positive and negative depatures, closely related to types of weather.

2. They appear to give a rather definite picture of the character and extent of the changes in pressure distribution which accompany changes in weather types.

3. They give an indication of the degree to which an established type will predominate in a given area, and of the completeness and probable duration of a change, once it has taken place. The extent of territory in which an established type will continue or in which a change of type is likely to occur is also indicated.

4. In some cases at least they afford some warning of impending changes.

5. If data were available promptly, the use of such maps in connection with the daily weather maps would help the forecaster to decide at the time of examining his synoptic charts whether the cyclones and anticyclones would follow the same paths as in the recent past, or be temporarily deflected to other paths, or show a definite and persistent change of track and character.

6. For the particular period studied they showed a long persistence of type in Asia, somewhat less stable conditions in America, and frequent changes of type in Great Britain and Europe. These conditions, as partially indicated in the intorduction, are more or less typical of these three continents.

LITERATURE CITED

(1) W. G. Kendrew: Climate, 1930, p. 284.
(2) A. J. Henry: Notes, Mo. Wea. Rev., 56: 511.
(3) C. D. Reed: Monthly Forecasts by Correlation, Mo. Wea. Rev., 53: 249–251.
(4) J. R. Weeks: What Will the Winter Be? Bul. Amer., Metl. Soc., 14: 17–18.
(5) N. A. Hessling: Variable Features of Barometric Depressions and Anticyclones as a Basis for Seasonal Forecasting, Mo. Wea. Rev., 55: 184–186.
(6) A. Wagner: Investigation of the Oscillations of the General Circulation. Translation in Mo. Wea. Rev., 57: 383.
(7) Mo. Wea. Rev., vols. 41 and 42.
(8) Climatological data for various States, Feb. 1914.
(9) Bowie, E. H., and Weightman, R. H.: Types of Storms of the United States and Their Average Movements. Mo. Wea. Rev., Sup. No. 1.

THE UPWARD SPEED OF AN AIR CURRENT NECESSARY TO SUSTAIN A HAILSTONE

By G. GRIMMINGER

[Aerological Division, Weather Bureau, Washington, D.C.]

Of the several theories which have been put forward to explain the formation of the hailstone, one requires that the hailstone be sustained and lifted upwards by an ascending air current until near full size is attained. This has led Humphreys (**1**) and Simpson (**2**) to compute the upward air speed necessary to support a hailstone in order to arrive at an estimate of the speed with which air rushes upward in a thunderstorm. Since neither of these writers gives any details of the method of computation used, I shall supplement their work by developing a correct method of computation and also by taking into account the effect of turbulence in the air stream, an effect known to be large.

It is easy to show (**3**) by the application of the principle of dimensional homogeneity that, provided compressibility is neglected, the aerodynamical resistance of a body is expressible in the form

$$R=\tfrac{1}{2}\rho L^2V^2f\left(\frac{LV}{\nu}\right) \tag{1}$$

which can be written in the dimensionless form

$$\frac{R}{\frac{1}{2}\rho L^2V^2}=f\left(\frac{LV}{\nu}\right) \tag{2}$$

where

R = aerodynamical resistance
ρ = density of the air
L = some linear dimension of the body
V = relative air speed
$\nu=\frac{\mu}{\rho}$ = kinematic coefficient of viscosity
μ = coefficient of air viscosity.

The quantity $\frac{LV}{\nu}$, called Reynold's number, is the independent variable in equation (2) which is used to compute the results of wind-tunnel tests on resistance, or drag. That is, $\frac{R}{\frac{1}{2}\rho L^2V^2}$ is [1] plotted against $\frac{LV}{\nu}$ and the resulting curve [2] is the graphical representation of the function $f\left(\frac{LV}{\nu}\right)$. The form of this curve depends on the shape of the body and the turbulence of the air stream, and is the same for all bodies geometrically similar to each other provided the air stream always has the same turbulence. Since the hailstone will be assumed to be spherical, we shall confine our attention to the resistance of spheres. In this case L is replaced by D the sphere diameter, and equations (1) and (2) become

$$R=\tfrac{1}{2}\rho D^2V^2f\left(\frac{DV}{\nu}\right) \tag{3}$$

$$\frac{R}{\frac{1}{2}\rho D^2V^2}=f\left(\frac{DV}{\nu}\right) \tag{4}$$

[1] The ratio $\frac{R}{\frac{1}{2}\rho L^2V^2}$ is usually denoted by C_D which is called the drag coefficient.

[2] Since $\frac{R}{\frac{1}{2}\rho L^2V^2}$ and $\frac{LV}{\nu}$ are both dimensionless, the curve of $f\left(\frac{LV}{\nu}\right)$ is independent of the size of the units used and is the same for all self-consistent systems of units.

Neglecting the effect of turbulence for the present, suppose the curve $f\left(\frac{DV}{\nu}\right)$ has been determined for a given sphere; then, since all spheres are geometrically similar, this same curve applies to a sphere of any size.

If a hailstone is to be sustained by a vertical air current, the upward drag of the air on the hailstone must be equal to its weight. Hence,

$$\tfrac{1}{2}\rho D^2V^2f\left(\frac{DV}{\nu}\right)=\tfrac{4}{3}\pi\frac{D^3}{8}d_w\rho_h \tag{5}$$

where ρ_h is the specific gravity of the hailstone and d_w is the weight of water per unit volume. For a hailstone of given size and specific gravity and for given conditions of pressure and temperature of the atmosphere, ρ, D, ν, d_w, and ρ_h are constants so that equation (5) can be written

$$V^2f(K_1V)=K_2 \tag{6}$$

where K_1 and K_2 are known constants and where $f(K_1V)$ is known for any given value of V. It is now required to solve equation (6) for V, for it is this value of V which is necessary to sustain the hailstone. It would be a simple matter to find this value of V if $f(K_1V)$ were constant, but experiment shows that the variation of $f(K_1V)$ with K_1V is far too large to be considered even approximately a constant. In this connection I might say that although reference **2** gives no information as to Simpson's method of computation, I have been able to determine by backfiguring from his results that $f(K_1V)$ was treated as a constant; his values of V must therefore be considered as uncertain. Since the function $f(K_1V)$ is not known analytically but only as a curve, equation (6) must be solved graphically. To do this, let

$$y=V^2f(K_1V)-K_2 \tag{7}$$

so that the desired value of V is that which makes $y=o$. The procedure is to compute y for different values of V, plot y against V, and then pass a curve through these points; the required value of V is that at which this curve crosses the V axis. This method of computation is entirely general and can be used to compute the wind speed necessary to produce a given force on any body provided its resistance curve $f\left(\frac{LV}{\nu}\right)$ is known.

So much for the method of computation. Let us now consider the effect of turbulence in the air stream. The turbulence to be considered here is not the large scale turbulence usually thought of in connection with meteorology, but turbulence of a very much smaller scale such as is present in wind tunnel air streams and which is called fine-grained turbulence. In turbulence of this kind, small variations from the mean wind speed and direction occur many times in 1 second. Experiments show that the resistance of a sphere is particularly affected by the amount of turbulence of this type present in the air stream (**4**) and that the resistance curve of a sphere is

different for different amounts of turbulence. Since this is the case, it is evident that the vertical air speed necessary to sustain a hailstone depends on the turbulence in the air current; in order to see how the necessary vertical speed is affected by turbulence, it is necessary to use the method outlined in connection with equation (7), using resistance curves $f\left(\frac{DV}{\nu}\right)$ determined under various conditions of turbulence. This has been done and the resulting values are given in table 1 for hailstones of various diameters.

The computations have been carried out on the assumption that the density of the air is three fifths that at sea level (the same density as used by Humphreys), corresponding to a height of about 14,000 feet. The coefficient of air viscosity is based on an assumed air temperature of 0° C.; the specific gravity of the hailstone is assumed to be 0.8. In the English gravitational system of units we have the following values:

$$\rho=\frac{3}{5}\times 0.00237=0.001422 \text{ slugs per cubic foot}$$

$$\mu=0.3575\times 10^{-6}$$

$$\text{Reynold's number}=\frac{DV}{\nu}=\frac{DV\rho}{\mu}=\frac{0.001422}{0.3575\times 10^{-6}}DV$$

$$=3978DV$$

$$d_w=62.4 \text{ pounds per cubic foot.}$$

As a sample computation let $D=1.0$ inch $=\frac{1}{12}$ foot. Equation (5) then becomes

$$\frac{1}{2}\times 0.001422\times\frac{1}{(12)^2}\times V^2 f\left(3978\times\frac{1}{12}\times V\right)=\frac{4\pi}{3}\times\frac{1}{8\times(12)^3}\times 62.4\times 0.8,$$

or

$0.000004938V^2 f(331.5V)=0.01513$, which gives
$V^2 f(331.5V)=3065$ for equation (6),* and
$y=V^2 f(331.5V)-3065$ for equation (7).

Let

$$V=60\ \frac{\text{mi.}}{\text{hr.}}=88.0\frac{\text{ft.}}{\text{sec.}};$$

then

$$y=(88.0)^2 f(331.5\times 88.0)-3065,$$

or

$$y=7744\,f(0.292\times 10^5)-3065.$$

Using the resistance curve of figure 12, page 11 of reference 5, it is found that $f(0.292\times 10^5)=0.36$. Hence, $y=7744\times 0.36-3065=2790-3065=-275$, and by computing $y=V^2 f(331.5\ V)-3065$ for a few more values of V it is found

that $y=o$ when $V=63\ \frac{\text{mi.}}{\text{hr.}}$

*It will be noted that from $V^2 f(331.5\ V)=3065$ we can get the corresponding equation for a sphere of any diameter. Thus, for $D=2.0$ inches equation (6) becomes $V^2 f(331.5\times 2\times V)=3065\times 2$, or $V^2 f(663.0\ V)=6130$.

The values in column A of table 1 were obtained by using the resistance curve given in figure 12, page 11 of reference **5**. This curve was determined under conditions of excessive turbulence in the air stream (**6**) so that the values in column A correspond to a very turbulent condition. The values in column B were obtained by using the right hand resistance curve[3] in figure 7 (**7**). These measurements were made in an air stream having but little turbulence (**6**) so that the values in column B correspond to a condition of little turbulence. The values in column C were computed by using the resistance curve[4] in figure 16, page 14 of reference 5. These measurements were made by dropping spheres in the free air when there was extremely little turbulence; hence, the values in column C correspond to very little turbulence.

TABLE 1.—*Upward air speed necessary to sustain a spherical hailstone.*

Diameter of stone	A Much turbulence	B Little turbulence	C Very little turbulence
Inches	*Miles per hour*	*Miles per hour*	*Miles per hour*
1.0	63	65	[1]54
2.0	206	91	[1]78
3.0	244	112	[1]101
4.0	258	264	[1]123
5.0	272	--------	157

[1] Resistance curve interpolated. See footnote 4.

The large effect of turbulence is seen by comparing corresponding values of columns A and C. For instance, the upward air speed necessary to sustain a 2-inch hailstone may be anything from 78 $\frac{mi}{hr}$ to 206 $\frac{mi}{hr}$ depending on the state of turbulence in the ascening current of air. It is impossible to say definitely how much fine-grained turbulence might be present in ascending air currents which occur in thunderstorms. The few measurements which have been made show that under calm conditions the amount of such turbulence present in the free air is less than that in the smoothest of wind tunnels (**5**, p. 17). I understand that, in a paper not yet published, von Karman, of the California Institute of Technology, gives the results of measurements in the free air which confirm this. It might be argued that since the influence of the wind tunnel walls, honeycomb, and propeller is not present in the free air, the turbulence should vanish at a sufficient height above the surface of the earth. If this view is adopted, we might expect the necessary upward speeds to be even less than those in column C.

In order that its layer structure may be explained, the hailstone is usually assumed to rise and fall from one to several times before finally dropping to the earth. These vertical excursions are ordinarily attributed to variations in the upward air speed. It is interesting to note from table 1, however, that variations of the turbulence in the

[3] This curve is based on the equation $\frac{R}{\frac{1}{2}\rho\pi\frac{D^2}{4}V^2}=f\left(\frac{DV}{\nu}\right)$. Consequently for $D=1.0$ inch equation (6) becomes $V^2 f(331.5\,V)=3902$.

[4] This resistance curve was extended to smaller values of $\frac{DV}{\nu}$ by using $\frac{R}{\frac{1}{2}\rho D^2V^2}=0.515$ at $\frac{DV}{\nu}=0.0014\times 10^6$. See bottom of p. 16, reference 5.

upward air current could also cause a succession of rises and falls of the hailstone, even though the upward air speed remained the same. At any rate, it is seen that variations in turbulence may be a factor in the vertical excursions of the hailstone.

LITERATURE CITED

(1) Humphreys, W. J.: The Uprush of Air Necessary to Sustain a Hailstone. Monthly Weather Review, vol. 56, 1928, p. 314.
(2) Giblett, M. A.: Line Squalls. Journal of the Royal Aeronautical Society, Great Britain, vol. 31, 1927, p. 528.
(3) Cowley, W. L., and Levy, H.: Aeronautics in Theory and Experiment. Edward Arnold, London, 1918. P. 90.
(4) Dryden, H. L., and Kuethe, A. M.: The Effect of Turbulence in Wind Tunnel Measurements. N.A.C.A. Technical Report No. 342, 1930.
(5) Bacon, D. L., and Reid, E. G.: The Resistance of Spheres in Wind Tunnels and in Air. N.A.C.A. Technical Report No. 185, 1924.
(6) Jacobs, E. N.: Sphere Drag Tests in the Variable Density Wind Tunnel. N.A.C.A. Technical Note No. 312, 1929, p. 8.
(7) Flachsbart, O.: Recent Researches on the Air Resistance of Spheres. N.A.C.A. Technical Memorandum No. 475, 1928. Translation from Physikalische Zeitschrift, vol. 28, 1927.

A BRILLIANT METEOR AND ITS CLOUD-LIKE TRAIL

By S. P. PETERSON

[Weather Bureau, Albuquerque, N.Mex., Mar. 24, 1933]

An unusually brilliant meteor was observed at 5:07 a.m on March 24, 1933, by Pilot C. W. Coyle, while flying a Transcontinental & Western Air Mail plane east from Albuquerque. At the time in question he was near Adrian, Tex., 235 miles east of Albuquerque, at a sea-level altitude of about 9,500 feet. At first it appeared as if a plane had suddenly turned on a landing light to the east of, and at an angular elevation of about 60° from, his position.

The meteor passed to the northward, seemingly at about his level, and looked like a ball of fire with pieces bursting from it, and left in its wake a great red trail tinged with blue. It disappeared to the westward and seemed to strike the earth, or disintegrate, northeast of Tucumcari, N.Mex.

The meteor also was seen by Pilot F. E. Williams when he was over Acomita, N.Mex., some 55 miles west of Albuquerque, flying a Transcontinental & Western Air Mail plane westward. Suddenly the sky was brilliantly illuminated, and on looking for the cause he saw the meteor behind him at an indefinite distance. It also was seen by several persons in Albuquerque. A very luminous cloud of bluish-green color, apparently developed by the meteoric dust, seemed to be suspended in the sky to the east-northeast of Albuquerque over the Sandia Mountains. This cloud remained visible until lost in the light of dawn. It seems that there was some electric development in the atmosphere along the passage of the meteor, as Pilot Coyle said that the radio beam that he was following at the time was cut out by a roar of static. There was much haziness over eastern New Mexico, southeastern Colorado, and the Texas Panhandle the latter part of the 24th, practically all the 25th, and locally in those sections early on the 26th. Whether this was owing to meteoric dust or to other causes is not known. The visibility at Dilia, N.Mex., and at Tucumcari, N.Mex., was reduced to one-half mile at the time of the greatest density of the haze. This meteor attracted the Nation-wide interest of scientists, who have made an extended search for its location.

The accompanying photograph of this meteor cloud was taken at 5:30 a.m. The camera was facing toward the east and the luminous cloud was apparently resting on the crest of the Sandia Mountains. There were a few scattering stratus and strato-cumulus clouds but these were still in the shadow of the earth, while the meteor cloud was in full sunshine, as shown in the picture.

When first seen by the photographer, the luminous cloud, looking like a magnesium flare, was midway between the top of the picture and the crest of the mountains, but it gradually settled, while he was preparing his camera, to the position in which it is here shown.

TROPICAL DISTURBANCES OF JULY 1933

By CHARLES L. MITCHELL

June 27–July 6.—This disturbance was first noted the evening of June 27, central in about latitude 9° north and longitude 59° west. It was the earliest known in that general area and also the only one in a record of nearly 50 years to pass south of the Island of Trinidad and over the northeastern corner of Venezuela. On the morning of June 28 the center was over the southwestern part of the Gulf of Paria. An Associated Press dispatch from Port of Spain, estimated that in the Island of Trinidad there were 13 deaths, 1,000 persons rendered homeless, about $3,000,000 property damaged, practically all in the southern part of the island.

Through the courtesy of the United States Chargé d'Affaires at Caracas, Venezuela, the following report has been received:

> *Hurricanes in eastern Venezuela.*—On June 28 a devastating hurricane swept through eastern Venezuela, the towns of Carúpano and Rio Caribe, on the mainland, and the island of Margarita suffering the most damage. Telephonic and telegraphic communications were cut for several days. Many business houses and private dwellings were destroyed, several small trading and fishing boats sunk and a number of lives lost. The losses from this hurricane alone are estimated at several millions of bolivars [1 bolivar= 19.3 cents]. During July there were several more hurricanes in the vicinity of Pedernales, at the mouth of the Orinoco, and along the river itself up as far as the Apure. However, most of them did not strike towns of any size.

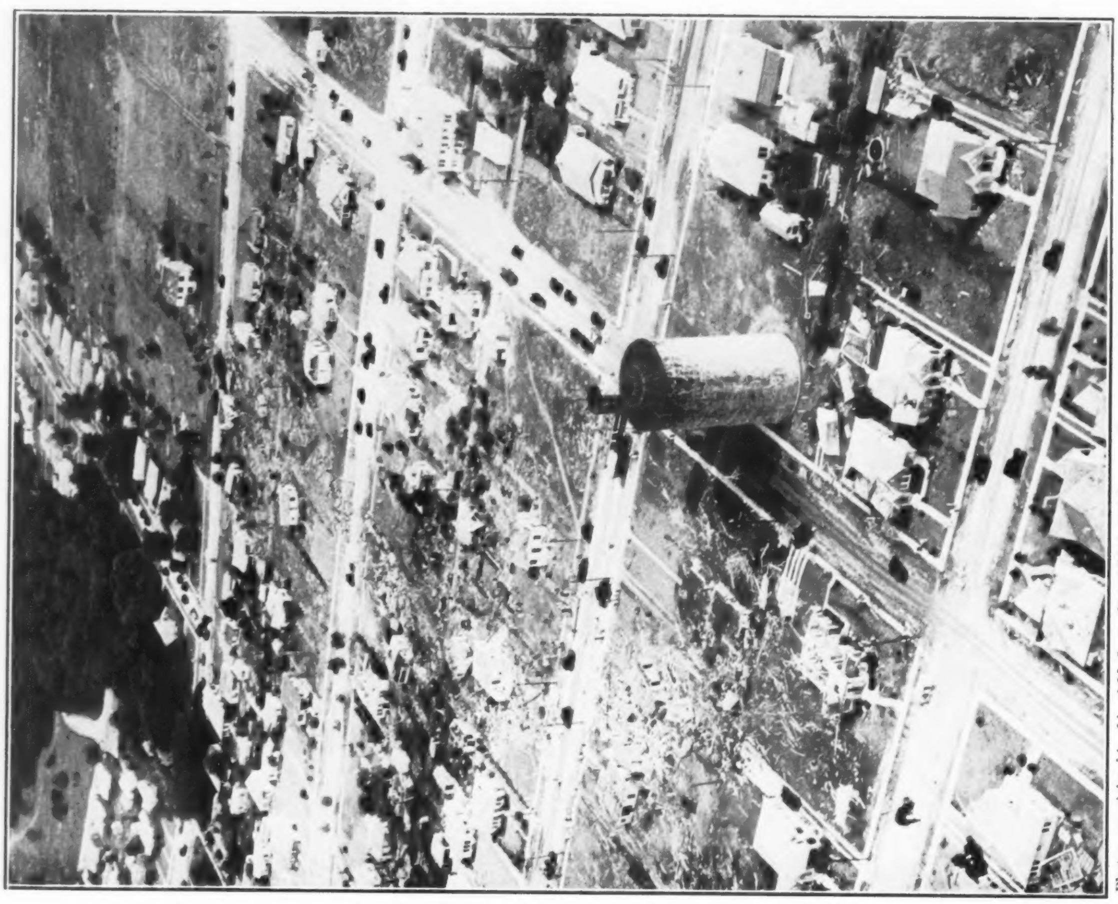
During the next several days this disturbance moved first west-northwestward and later northwestward over the Caribbean Sea. It passed over extreme western Cuba the night of July 2–3, but did not cause much damage. By the morning of the 4th a strong area of high pressure, that spread southward from Hudson Bay over the eastern part of the United States, blocked the northward progress of this disturbance and deflected it toward the west. After moving westward until the evening of the 5th it turned southwestward and crossed the Mexican coast line about midway between Tampico and Brownsville, Tex., the evening of the 6th, where it caused several deaths and considerable property damage in the sparsely-settled coast region.

The usual twice-daily advisory warnings were issued in connection with this disturbance. Northeast storm warnings were ordered at noon of the 5th from Brownsville to Port O'Connor, Tex., and the warnings at Browns-

(To face p. 200)

Brooks Studio, Albuquerque, N.Mex.

Luminous meteor cloud



Photos copyrighted by Lloyd M. Long, Fairchild Aerial Surveys, Inc., Dallas, Tex.

Figure 1 first portion and figure 2 later portion of path of tornado at Dallas, Tex., July 30, 1933. Tornado moved from bottom of photo to top.

ville were changed to hurricane at 4 p.m. of the same date.

July 14-19.—On the morning of the 14th a minor disturbance appeared near St. Kitts, West Indies. It moved almost directly westward, passed near Jamaica on the 16th, over the Yucatan Peninsula on the 18th, and finally inland north of Vera Cruz, Mexico, the night of the 19th-20th.

July 21-27.—This disturbance, which also was of minor intensity, was first noted about 200 miles northwest of Progreso, Yucatan, the morning of the 21st. It moved northwestward to the coast of Texas, then inland near Matagorda Bay the night of the 22d-23d, and finally dissipated near Memphis, Tenn., during the 27th.

July 25-August 5.—This disturbance was centered a short distance southeast of the Island of Antigua, West Indies, the morning of the 25th. It passed south of St. Thomas the following night, causing a wind velocity of 60 miles per hour from the northeast. Continuing west-northwestward its center passed north of Puerto Rico on the 26th and almost over Turks Island on the 27th. The lowest barometer reading at Turks Island was 29.37 inches, accompanied by a wind velocity estimated as 85 miles per hour from the northeast. The disturbance moved northwestward during the 27th-28th, then west-northwestward over the northern Bahamas. The center crossed the coast line of Florida a short distance south of Fort Pierce on the 30th, accompanied by a wind at that place of 60 miles per hour from the southeast. However, no great amount of damage resulted as the disturbance moved westward over the Florida Peninsula and passed into the Gulf of Mexico between Tampa and Fort Myers. Storm warnings were displayed on the east Florida coast from Miami to Titusville and on the west coast from Tarpon Springs to Punta Rassa.

This disturbance continued to move westward but vessel reports on the 1st and 2d indicated a decrease in intensity. From the morning of the 3d until the center passed over the coast line near Brownsville no vessel reports were received near or west of the center, and it was impossible to indicate accurately its position or intensity. However, advices were issued twice daily giving estimates of its position and probable movement until noon of the 3d when storm warnings were ordered for the Texas coast between Freeport and Brownsville. On the evening of the 3d Texas stations were advised that the center probably would reach the south Texas coast between Brownsville and Corpus Christi and be attended by strong shifting winds, possibly reaching gale force near the center with moderately high tides from Port O'Connor southward to Brownsville. The advices on the morning of the 4th were that the center would cross the Texas coast between Corpus Christi and Brownsville, but somewhat nearer Brownsville, and that winds would reach gale force over a very small area but probably would not attain hurricane velocity. The center crossed the coast nearly over but slightly south of Brownsville during the early night of the 5th with greatly increased intensity, the highest velocity being 72 miles at Brownsville. No doubt the increase in intensity began as early as the 4th. Considerable damage was caused in the vicinity of Brownsville and over a strip westward to Monterey, Mexico, owing largely to torrential rains.

THE DALLAS, TEX., TORNADO OF JULY 30, 1933

By GORDON E. DUNN[1]

[Weather Bureau, Washington, August 1933]

A tornado struck the Oak Cliff section of Dallas, Tex., about 4:15 p.m., eastern standard time, July 30, 1933. It moved from south-southeast to north-northwest for a distance of about 2 miles, killing 4 persons, injuring about 30, and effecting a property loss estimated at $500,000, though over part of its path there was little or no damage.

This tornado occurred in connection with a rather severe thunderstorm, but the pressure distribution was decidedly of a nontornadic type. On the 28th and 29th a rain area moved steadily northward from the West Gulf coast, reaching Dallas early on the 30th, but attended by no surface cyclonic circulation. The rainfall ranged from 4 to 6 inches in northern Texas and southern Oklahoma. The 5 a.m. airplane flight at Dallas on the 30th showed a weak lapse rate with rather high temperature to top of flight with a very high relative humidity—100 percent over a considerable portion of the vertical air column—and, of course, high absolute humidity. Twenty four hours later the lapse rate was still about the same, but the relative and absolute humidity had greatly decreased. The upper-air map was rather blank over this area owing to extensive cloud cover, but on the evening chart Dallas reported the highest wind velocity east of the Rockies, 36 miles per hour from the south-southwest at 8,000 feet and 45 to 47 miles from 3,000 to 6,000 feet. There was some slight evidence of cyclonic circulation aloft.

The accompanying aerial photographs taken of the wreckage of this storm by the Fairchild Aerial Surveys, Inc., of Dallas, and kindly furnished by them for use in this article, present a clear and unusual picture of the trail of a tornado. The serpentine path, rotation, and explosive effects are clearly evident. The direction of rotation is less evident, but Mr. J. A. Riley in his personal inspection of the storm area says, "there appears very strong evidence that the rotation was counterclockwise." Figure 1 shows the area of major destruction beginning shortly beyond the place where the tornado first touched ground. Between the areas covered by figures 1 and 2 there is a vacant lot where for one quarter mile little damage could be done. In figure 2 the serpentine path is clearly shown. The tornado continued on beyond this area for a short distance with little damage.

[1] Based on a report by Mr. J. A. Riley, official in charge, Weather Bureau Airport, Dallas, Tex.

EXCESSIVE RAINFALL OF JULY 22-25, 1933, IN LOUISIANA AND EXTREME EASTERN TEXAS

By R. A. DYKE

[Weather Bureau Office, New Orleans, La., August 1933]

Although of only slight intensity, as indicated by atmospheric pressure and winds, the disturbance which reached the Texas coast late on July 22, 1933, and moved very slowly overland, was attended by a rainfall that seldom has been exceeded in the United States in tropical storms. This disturbance was over extreme eastern Texas and Louisiana on July 22-26, 1933, and moved to Arkansas on the 27th, after which it apparently "filled up" and disappeared.

The 4-day rainfall for extreme eastern Texas and the greater part of Louisiana, on July 22-25, 1933, is charted

Excessive rainfall (inches) July 22-25, 1933 in Louisiana and adjacent portions of Arkansas and Texas.

herewith. Within the 8-inch isohyetal is an area of about 25,000 square miles, with average rainfall of 12.50 inches. There are two principal centers of maximum fall, namely, Shreveport, La., with 19.46 inches and Logansport, La., with 22.30 inches. Considering area-depth-time relations, this ranks close to the most intense of the larger rainstorms that have been recorded in the United States, the dates and circumstances of which were: June 27-July 1, 1899, in east Texas, attending a tropical disturbance of slight intensity, which, however, has little or no previous history concerning its movement, and which was blocked in its northward advance and remained over south Texas until it disappeared; August 17-19, 1915, attending a tropical hurricane, which prolonged heavy rainfall over extreme eastern Texas while recurving slowly from a northwestward to a northeastward course; July 6-10, 1916, in the east Gulf States, attending a tropical hurricane which was greatly retarded in its movement in turning eastward from over Mississippi to Alabama; July 14-16, 1916, in South Carolina and the Southern Appalachian region, attending a tropical hurricane which moved inland across South Carolina from the Atlantic and apparently died out over western North Carolina; and March 12-16, 1929, in southern Alabama, with a trough of low pressure over the Central States. (For charts and descriptions of these rainstorms, see "Storm Rainfall of the Eastern United States, Technical Reports, pt. 5, published by the Miami, Ohio, conservancy district, pp. 146, 169, 176-178, and 196-198; and "Weather Abnormalities in the United States; Excessive Rains and Floods in Southeastern Alabama", by Alfred J. Henry, MONTHLY WEATHER REVIEW, vol. 57, pp. 319-323. The torrential rainfall of September 8-10, 1921, centering at Taylor, Tex., is of smaller area than the rainstorms named above.)

Preceding the disturbance as it moved northward the wind circulation was definitely cyclonic along the Louisiana and Texas coasts up to elevations of about 12,000 feet, the winds closely following the coast line. This gave easterly winds over western Louisiana and extreme eastern Texas.

The center of greatest rainfall for the 24 hours ending at 7 a.m., July 23, was over the Sabine River Basin from Port Arthur to Bronson, Tex. During the 24 hours ending at 7 a.m., July 24, the area of maximum rainfall advanced northward to the upper Sabine Basin. Observations at surface and aloft indicate that the southerly winds extended northward during this period and the easterly winds continued over northwestern Louisiana and extreme northeastern Texas. Surface winds and clouds were still from the east over Shreveport during the 24th, with lowest pressure remaining in that vicinity, while the center of greatest rainfall moved eastward to the Red River Valley in northwestern Louisiana for the 24 hours ending at 7 a.m. of the 25th. Over interior sections a broad and deep air current from the northeast prevailed to the northward of Shreveport, while south to southwest winds prevailed along the Gulf Coast. Twenty-four hours later the center of maximum rainfall was over northeastern Louisiana, with precipitation somewhat diminished.

During the period of heavy rains, thunderstorms occurred near the coast but no thunderstorms were reported from interior localities of western Louisiana except at Dodson. All of the facts indicate that southerly winds were meeting and in considerable part ascending over easterly winds in the area of heavy rains during the greater part of the period of excessive precipitation.

The heavy rainfall was not confined to the usual forward region of the cyclone but persisted for 24 hours or more in localities that were some distance to the southward. This is in harmony with Cline's findings regarding tropical cyclones that cease to advance, or suffer pronounced retardation, in which precipitation occurs more generally about the cyclonic center, as contrasted with

advancing tropical cyclones, in which the precipitation is nearly all confined to the forward half.

The foregoing description of conditions is not offered as an adequate explanation of the excessive rainfall. In this, as in many other instances of unusual rainfall, data are insufficient for a satisfactory basis of explanation. From what is known of the precipitation usually attending slight disturbances, the effects seem out of proportion to the apparent preliminary conditions. We may suggest that the angle of inclination of the ascending air in the present instance probably was relatively steep and that condensation aided in intensifying and prolonging the ascent of air, while the continued presence of the disturbance, with its wind circulation, provided the means by which the warm, moist Gulf air was fed into the precipitation machine.

Losses of cotton and other crops in overflowed fields in northern Louisiana, attending and following the heavy rains, amounted to at least a few million dollars. The Red River, which was low when the rain began, had ample channel to pass the runoff, at the rate at which it was received, without reaching bankful stage; but a number of smaller, ungaged streams overflowed.

The following is quoted from a report by Mr. J. W. Cronk, in charge of the Shreveport, La., office of the Weather Bureau:

"The drainage system in this section was so ineffectual that many thousands of acres of land were deeply covered with water for many days, with still a thousand acres or more not free from this water in lower Bossier Parish at the time of making this report, August 10. In Caddo Parish, on the right bank of Red River, where the drainage was inadequate, there were from 10 to 20 thousand acres of farm land more or less badly flooded, and in Bossier Parish, on the left bank of Red River, there were from 50 to 75 thousand acres or more also badly flooded, with some parts of the paved highways covered by water for 2 weeks. Resulting losses in this section, mainly to the nearly matured cotton crop, are estimated as being between one and two million dollars, at a low valuation."

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

International commission for the exploration of the upper air.
Procès-verbaux des séances de la réunion de la Commission internationale pour l'exploration de la haute atmosphère, tenue à Madrid mars 1931. 158 p. figs. plates (part fold.) 24½cm. (Sec. de l'Organ. mét. intern. No. 8.)

International geodetic and geophysical union. Section of meteorology.
Quatrième assemblée générale. Stockholm—août 1930. Procès-verbaux des séances . . . 2. Annexes. Paris. 1933. 170 p. 24½ cm.

International meteorological organization.
IIe rapport de la Commission internationale de l'année polaire 1932–33. Compte-rendu des travaux de la commission pendant sa deuxième année de travail. Procès-verbaux des séances de la réunion à Innsbruck septembre 1931. Leyde. 1932. 188 p. figs. plates (some fold.) 24½ cm. (Sec. de l'Organ. mét. internat. No. 12.)

International meteorological organization.
Les messages symoptiques du temps. Les messages pour l'aéronautique. Leyde. 1933. 163 p. suppl. 60 p. 24½ cm. Fasc. 4. Édition 1933. (No. 9.)

Laurens, Henry. The physiological effects of radiant energy. New York. 1933. 610 p. illus., diagrs. 23½ cm. (American chemical society. Monograph series. [no. 62.]) Bibliography: p. 577–593.

Lwów. Université. Institute de géophysique et de météorologie.
Communications. v. 5. Nos. 57 à 66 des résultats des recherches de Henryk Arctowski et de ses collaborateurs . . . faites à la Société des naturalistes polonais et publiées dans la revue "Kosmos." 1930. p. 395–605. figs. plates. 23 cm. [Polish text: French abstract.]

U.S. Agriculture dept. Forest service.
List of references concerning lightning. List compiled by the General petroleum corp . . . Missoula. [1933.] 134 p. 27 cm. [Typewritten.]

U.S. Weather bureau.
Instructions for making four-hourly reports. Washington. 1933. 19 p. 27 cm. (Circular, July 15, 1933.) [Manifolded.]

U.S. Weather bureau.
Instructions for reporting pilot balloon observations. Washington. 1933. 19 p. 27 cm. (Circular, July 1, 1933.) [Manifolded.]

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING JULY 1933

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1932, REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged above normal at all weather bureau stations at which normal incidence measurements are made.

Table 2 shows a deficiency in the total solar radiation received on a horizontal surface at Madison, Pittsburgh, La Jolla, Gainesville, and Miami, and an excess at all other stations.

Turbidity measurements made on the 6th show that this was an exceptionally clear day for July. Readings obtained on the following day indicate greatly increased turbidity which was the forerunner of a cloudy period that persisted until the 18th.

Polarization measurements obtained at Washington on 4 days give a mean of 57 percent with a maximum of 59 percent on the 19th. At Madison, observations obtained on 8 days give a mean of 64 percent. with a maximum of 72 percent on the 24th. The Washington values are close to the July normals, but the Madison values were slightly above normal.

TABLE 1.—*Solar radiation intensities during July 1933*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D.C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A.M.					P.M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 5	10.59		0.87								10.59
July 6	10.97	0.70	0.85	1.02	1.19	1.43	1.17				7.57
July 7	14.60	0.38	0.43	0.63	0.96	1.26	0.94				12.24
July 18	11.38				0.98	1.32					10.97
July 19	15.11			0.84	1.15	1.30					12.68
July 29	17.96					1.18					16.20
Means		(0.54)	0.72	0.83	1.07	1.30	(1.06)				
Departures		−0.05	+0.04	+0.05	+0.16	+0.10	+0.06				

Madison, Wis.

Date	75th mer. time	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	Local mean solar time
July 15	10.59					1.44					10.21
July 17	10.97		0.89	1.03	1.18	1.42					9.14
July 18	12.24				1.05	1.39					12.68
July 19	13.61		0.72	0.88	1.03						15.65
July 24	11.38		0.99		1.26	1.45					8.48
July 25	11.38		0.95	1.09	1.20	1.40					10.21
July 26	9.83					1.37					12.24
July 27	10.59		0.75	0.87	1.07	1.38					11.81
July 28	11.38	0.63	0.74	0.86	1.07	1.32					8.18
July 29	15.11	0.61	0.69	0.86	1.02						14.60
Means		(0.62)	0.82	0.93	1.11	1.40					
Departures		−0.08	+0.02	+0.01	+0.04	+0.10					

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during July 1933*—Continued

Lincoln, Nebr.

Date	Sun's zenith distance										
	8a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A.M.					P.M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.9	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
July 5	11.38		0.73	0.82	1.04	1.32					14.60
July 6	10.59					1.34	1.00	0.83			12.68
July 13	16.92				1.18	1.38					16.79
July 15	14.60					1.38					14.10
July 16	11.38		0.95	1.08	1.24	1.48					8.18
July 18	16.20		0.77	0.88							16.20
July 20	18.59	0.65	0.75			1.30	1.00				17.37
July 21	17.96					1.24	0.96		0.69		20.57
July 22	13.13						0.99	0.80	0.68	0.57	14.60
July 24	10.97	0.71	0.83	0.97	1.14	1.33	1.14	1.02	0.88	0.76	12.68
July 25	12.24	0.73	0.84	0.97	1.16	1.36	1.09	0.96	0.84	0.71	12.68
July 26	12.24			1.05	1.19	1.38	1.16	0.98	0.87	0.75	11.38
July 27	10.97		0.82	0.98	1.11	1.43	1.15	0.94	0.77	0.68	11.81
July 28	11.81		0.84	0.92	1.13	1.40	1.12	0.91	0.75	0.68	9.47
July 29	12.24		0.86	1.02	1.18	1.40					13.13
Means		0.70	0.82	0.97	1.15	1.36	1.07	0.92	0.78	0.69	
Departures		+0.04	+0.04	+0.07	+0.07	+0.03	±0.00	+0.03	+0.04	−0.01	

Blue Hill, Mass.

Date	75th mer. time	5.0	4.0	3.0	2.0	1.9	2.0	3.0	4.0	5.0	Local mean solar time
July 1	14.6			0.96	1.06						15.6
July 6	11.8				1.04		0.86				12.2
July 10	11.8				0.99						10.6
July 12	10.2						1.05	0.86			9.1
July 13	9.8			0.83	0.97	1.23	1.12	1.03	0.97	0.92	12.7
July 14	11.4					1.33	1.11	0.91	0.77	0.67	9.8
July 18	14.1						1.02				6.8
Means				0.87	1.02	1.28	1.03	0.93	0.87	0.80	

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Gram calories per square centimeter													
	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Gainesville	Miami	New Orleans	Riverdale
1933	*cal*	*cal.*	*cal*	*cal.*	*cal.*	*cal.*	*cal.*	*cal*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
July 2	624	513	608	514	452	711	486	396	494	341	414	479	334	663
July 9	439	505	555	570	524	722	505	470	646	353	257	491	390	640
July 16	553	501	602	556	440	726	500	281	670	293	331	474	335	642
July 23	452	570	629	584	434	664	340	523	610	([1])	537	549	337	550
	Departures from weekly normals													
July 2	+116	−17	+29	+63	+19	+22	+2		−124	−71	−78	−66		
July 9	−50	−29	−20	+120	+95	+40	+10		−52	−45	−202	−49		
July 16	+76	−17	+30	+108	+20	+62	+15		+82	−134	−133	−76		
July 23	−36	+64	+80	+156	+20	+26	−141		+34		+69	−5		
	Accumulated departures on July 29													
	+6825	+3976	+2513	+9450	+7616	+5481	+336		+280	−8038	−12124	−3269		

[1] Pyrheliometer undergoing repair.

TABLE 3.—*Solar radiation measurements, and determinations of atmospheric turbidity factor, β, Washington, D.C., July 1933*

[Values in italics have been interpolated]

Date and solar hour angle	Solar altitude, h.	Air mass, m.	I_m	I_v	I_r	β	Blueness of sky	Atmospheric dust particles per cubic centimeter	Notes: (skylight polarization, P.) clouds, etc.
July 6									
			gr. cal.	gr. cal.	gr. cal.				
5:55 a	14-55	3.84	0.881	*0.652*	0.504	0.035		449	
5:51 a	15-40	3.65	.899	.655	*.507*	.040			
5:40 a	17-43	3.26	.985	.700	*.564*	.042			
5:36 a	18-28	3.13	1.008	*.704*	.568	.040			
5:06 a	24-05	2.44	1.071	*.772*	.596	.055			
5:01 a	25-01	2.35	1.108	.775	*.598*	.045	6		P=58.4%
0:38 a	71-58	1.05	1.421	.828	*.690*	.038			
0:33 a	72-21	1.05	1.411	*.830*	.690	.040			
3:24 p	43-55	1.44	1.302	.830	.640	.035			
3:28 p	43-08	1.46	1.304	.832	*.640*	.035			
3:52 p	38-19	1.61	1.257	.754	*.630*	.040			
3:56 p	37-42	1.63	1.226	*.756*	.628	.045			
4:26 p	32-09	1.88	1.223	*.864*	.660	.055			
4:36 p	31-30	1.91	1.192	.865	*.658*	.070			
July 7									
5:56 a	14-38	3.92	.485	.284	*.220*	.065		905	
5:52 a	15-27	3.72	.512	*.286*	.222	.070			
5:34 a	18-50	3.08	.615	*.348*	.288	.065			
5:28 a	19-58	2.92	.633	.349	*.290*	.070			
4:49 a	27-24	2.17	.910	.550	*.460*	.072			
4:44 a	28-21	2.10	.917	*.552*	.462	.075	5		P-55.7%
3:21 a	44-28	1.43	1.147	*.732*	.608	.100			
3:16 a	45-26	1.39	1.130	.734	*.610*	.120			
1:20 a	66-22	1.09	1.232	.823	*.630*	.090			
:16 a	67-00	1.09	1.223	*.825*	.626	.095			

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Perkins, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1933	h. m.	°	°	°			
July 1 (Naval Observatory)	10 40	No spots					
July 2 (Naval Observatory)	14 8	No spots					
July 3 (Mount Wilson)	9 4	No spots					
July 4 (Naval Observatory)	10 21	No spots					
July 5 (Naval Observatory)	11 15	No spots					
July 6 (Naval Observatory)	10 5	−66.0	66.3	+6.0		31	31
July 7 (Naval Observatory)	13 24	−78.0	39.3	+6.0		12	
		−53.0	64.3	+7.0		22	34
July 8 (Naval Observatory)	10 32	−65.0	40.6	+6.5	9		
		−40.5	65.1	+7.5		19	28

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1933	h. m.	°	°	°			
July 9 (Mount Wilson)	8 30	−51.0	42.5	+7.0	3		
		−29.0	64.5	+7.0		8	11
July 10 (Mount Wilson)	8 40	−15.0	65.2	+7.0		4	4
July 11 (Perkins Observatory)	13 30	No spots					
July 12 (Naval Observatory)	13 46	−65.0	345.9	−4.0		9	
		+14.0	64.9	+7.5		15	24
July 13 (Naval Observatory)	10 29	No spots					
July 14 (Mount Wilson)	8 35	−42.0	345.2	−5.0		4	
		+38.0	65.2	+5.0		7	11
July 15 (Mount Wilson)	8 25	+52.0	66.0	+7.0	2		2
July 16 (Naval Observatory)	12 56	No spots					
July 17 (Naval Observatory)	14 48	No spots					
July 18 (Naval Observatory)	11 24	No spots					
July 19 (Naval Observatory)	11 3	No spots					
July 20 (Naval Observatory)	13 36	No spots					
July 21 (Naval Observatory)	11 32	No spots					
July 22 (Naval Observatory)	11 35	No spots					
July 23 (Naval Observatory)	12 34	No spots					
July 24 (Naval Observatory)	10 45	No spots					
July 25 (Mount Wilson)	8 38	No spots					
July 26 (Mount Wilson)	11 20	No spots					
July 27 (Mount Wilson)	9 6	No spots					
July 28 (Perkins Observatory)	12 15	No spots					
July 29 (Naval Observatory)	11 5	No spots					
July 30 (Naval Observatory)	11 10	No spots					
July 31 (Perkins Observatory)	14 5	No spots					
Mean daily area for July							5

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JULY 1933

(Dependent alone on observations at Zurich and its station at Arosa)

[Observations furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

July 1933	Relative numbers	July 1933	Relative numbers	July 1933	Relative numbers
1	0	11	8	21	0
2	0	12	7	22	0
3	0	13	0	23	0
4	0	14	0	24	0
5	0	15	0	25	0
6	*Ec* 7	16	0	26	0
7	17	17	0	27	0
8	17	18	0	28	0
9	18	19	0	29	0
10	14	20	0	30	0
				31	0

Mean: 31 days=2.8.

c=New formation of a very small center of activity; E, on the eastern part of the sun's disk.

AEROLOGICAL OBSERVATIONS

[Aerological Division, W. R. Gregg, in charge]

By L. T. Samuels

Free-air July temperatures averaged moderately above normal at the stations listed in table 1, except Norfolk, Pensacola, and San Diego, where negative departures predominated. Relative humidity departures were small to moderate and in most cases of opposite sign to those of the temperature.

Resultant free-air wind velocities in the lower levels were generally less than normal with an excess of southerly components at a number of stations east of the Rockies. (See table 2.) At the higher levels the resultants were mostly close to normal with some excess of northerly components at a few of the central stations.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during July 1933*

Altitude (meters) m.s.l.	Cleveland, Ohio (246 meters) [1]		Dallas, Tex. (146 meters) [2]		Norfolk, Va. (3 meters) [3]		Omaha, Nebr. (300 meters) [4]		Pensacola, Fla. (2 meters) [3]		San Diego, Calif. (9 meters) [3]		Washington, D.C. (2 meters) [3]	
	TEMPERATURE (°C.)													
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	17.9	(5)	25.1	(5)	22.8	−2.6	20.4	(5)	26.0	−0.3	19.5	−2.3	22.6	−2.2
500	21.6	(5)	25.5	(5)	21.0	−3.1	21.8	(5)	24.3	−0.3	17.1	−1.7	22.5	0.0
1,000	20.2	+1.4	23.9	+1.9	18.5	−3.5	22.0	+0.7	21.7	−0.4	21.5	−1.1	21.5	+1.1
1,500	16.6	+1.0	21.2	+2.0			19.2	+0.8						
2,000	13.1	+0.4	18.2	+1.8	12.7	−3.1	16.3	+0.9	15.4	−0.5	23.3	+2.0	15.7	+1.1
2,500	10.5	+0.6	15.2	+1.8			13.1	+0.9						
3,000	8.2	+1.0	12.4	+2.0	7.6	−2.7	10.1	+1.2	9.3	−0.6	15.2	−3.1	9.5	+0.6
4,000	3.3	+1.6	7.0	+2.6			3.6	+1.3	3.9	−0.5	7.7	−3.1	4.5	+1.1
5,000	−2.5	+0.7	1.7	+1.8			−3.3	+0.3	−2.4	−0.7				
	RELATIVE HUMIDITY (PERCENT)													
Surface	77	(5)	79	(5)	77	+2	83	(5)	88	+3	80	+6	79	+8
500	57	(5)	74	(5)	68	+1	70	(5)	84	+5	86	+6	71	+5
1,000	51	−15	68	+1	66	+4	56	−3	80	+6	58	+9	64	+3
1,500	56	−9	68	+6			55	−3						
2,000	60	−1	70	+11	57	−2	53	−3	72	+3	31	0	63	+2
2,500	53	−2	68	+10			52	−3						
3,000	46	−5	64	+7	51	0	46	−8	65	+1	42	+2	58	+3
4,000	34	−7	56	−3			35	−17	63	+3	53	+2	49	+1
5,000	30	−19	51	+15			33	−19	52	+3				

[1] Temperature and humidity departures based on normals of Royal Center, Ind.
[2] Temperature departures based on normals determined by interpolating between those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.
[3] Naval air stations.
[4] Includes period from July 12–31 only. Temperature and humidity departures based on normals of Drexel, Nebr.
[5] Surface and 500-meter level departures omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

Weather Bureau observations made near 5 a.m.; Navy, observations near 7 a.m. (75th meridian time).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a.m. (E.S.T.) during July 1933*

[Wind from N=360°; E=90°, etc.]

Altitude (meters) m.s.l.	Albuquerque, N. Mex. (1,554 meters)		Atlanta, Ga. (309 meters)		Bismarck, N.Dak. (518 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (192 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface			5	0.4	51	1.1	147	1.5	176	2.1	260	2.8	185	0.5	190	1.2	149	1.8	123	0.6	176	0.5	124	2.9
500			186	0.6			170	8.7	212	3.3			225	3.5	255	3.1	200	5.1			203	2.8	124	5.7
1,000			164	1.4	160	2.3	173	8.7	285	3.2			243	2.7	293	3.5	214	5.2	206	1.2	206	3.2	133	5.1
1,500			187	1.4	259	1.2	167	7.0	293	5.8			274	3.4	290	2.4	231	1.6	301	2.2	209	3.0	136	3.7
2,000			217	1.8	265	2.8	161	5.0	292	6.3	242	4.3	287	2.4	288	3.9	325	1.0	286	4.1	191	2.6	140	3.6
2,500			235	1.8	276	4.6	136	3.5	291	5.6	220	5.3	297	2.2	293	3.8	343	1.0	275	7.3	185	3.0	144	3.6
3,000			210	1.7	274	5.9	121	3.7	318	5.0	245	4.6	317	2.3	285	4.5	328	0.7	269	8.8	184	2.6	135	2.5
4,000			37	0.9	278	7.8	80	3.7	324	3.8	275	4.0	344	2.7	287	4.6	16	1.3	256	13.7	211	1.4	170	1.2
5,000			15	1.7			71	3.6	277	7.2	277	5.8	355	2.2	294	6.5	78	0.8	260	14.9	227	1.3	185	1.2

Altitude (meters) m.s.l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (83 meters)		New Orleans, La. (2 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Phoenix, Ariz. (338 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D.C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	344	0.3	213	0.5	150	0.9	169	0.5	309	1.6	166	2.9	129	1.1	93	1.4	146	4.3	91	0.6	64	0.5	352	0.6
500	55	0.7	267	1.0	203	3.0	207	3.7	256	1.8	171	4.4	167	4.6	156	1.0			190	1.1	25	2.5	326	2.2
1,000	22	1.2	292	1.7	217	2.8	195	3.9	300	3.6	208	7.5	203	6.0	244	1.4			265	3.0	340	1.6	337	2.3
1,500	335	2.8	15	0.6	249	1.8	188	3.4	300	1.8	222	4.2	230	5.0	254	1.3	162	6.7	279	4.5	311	1.4	306	2.1
2,000	263	1.8	292	0.3	302	1.6	198	3.2	240	1.7	277	1.3	248	4.0	247	0.6	181	5.6	277	6.6	263	2.9	303	3.7
2,500	205	1.8	236	3.2	315	2.2	182	2.5	224	3.2	356	2.0	280	2.1	76	0.3	206	3.3	284	7.9	256	4.0	304	4.2
3,000	149	4.0	226	5.2	310	2.1	225	1.8	218	3.3	8	2.3	345	2.5	85	1.4	228	3.2	289	8.6	254	4.9	304	4.6
4,000	142	4.7	233	7.0	307	1.7					26	3.7	3	5.0	113	3.3	250	4.8	299	8.5	244	8.1	304	5.6
5,000			243	6.8	298	0.9					6	3.5	357	3.9	83	5.6	254	4.4	300	9.2			312	5.4

RIVERS AND FLOODS

By RICHMOND T. ZOCH

[River and Flood Divsion, Montrose W. Hayes, In Charge]

There were only minor floods in the rivers of the United States where flood service is maintained. They are listed in the table below.

Heavy rains in southern Mississippi, Louisiana, and in eastern Texas, occurred on July 15–16 and still heavier rains fell on July 23–26. They caused much flooding and damage in the creeks and small streams where it is not practicable to issue flood warnings. The damage was greatest around Shreveport, La., where 19.08 inches of rain fell in 72 hours.

Very heavy rains over the Bear Creek Valley (a small tributary to the South Platte River) caused considerable damage near Morrison, Colo., on July 7. The official in charge at Denver, Colo., comments as follows on this flood:

Floods of this kind are of common occurrence in the canyons along the eastern slope of the Rockies from Montana to New Mexico, and the Bear Creek Canyon region appears to be particularly susceptible to the excessive downpours that result in sudden violent rises in the mountain streams whenever the conditions are favorable for thunderstorms in this region. Thunderstorms in Denver and its vicinity had been indicated for several days prior to the time of occurrence of the flood and had been forecast, morning and night, beginning with the evening of the 3d. The distance from Denver to Morrison is approximately 15 miles.

On July 21 the Columbia River passed below the flood stage. The Columbia reached its crest in June and was 0.1 foot higher at Vancouver than it was in 1928, the year of the previous highest gage reading. This flood was quite similar to the 1928 rise. (See Mo. Wea. Rev., vol. 56, 1928, p. 240.) The following report of the official in charge of the Weather Bureau office at Portland, Oreg., is of much interest in this connection:

Over the drainage basin of the Columbia River the winter of 1932–33 was unusually cold. Precipitation was not greatly in excess of normal, as a whole, but from December to March, inclusive, most of that which occurred in the mountains was in the form of snow. In the annual snow bulletin, based on conditions at the close of March, the statement was made that the 1933 rise of the Columbia River, with normal conditions prevailing at the time of most rapid melting, would be considerably greater than usual, and that, if unusually hot weather should occur late in May or early in June, a stage of 23 or 24 feet might be reached by backwater in the Portland harbor.

April was dry but cold, and there was relatively little melting; moreover some additions were made to the snow supply at high levels.

May was unusually cool, and not until the closing days was the temperature high enough to cause rapid melting of snow at the higher levels. In some parts of the drainage basin there was an excess of precipitation, but the amounts over the basin as a whole were not excessive. However, because of the persistence of low temperature, there were considerable deposits of new snow in some of the higher areas.

The warm spell which began late in May caused a material rise in the Columbia, bringing the river to the flood stage of 15 feet at Vancouver, Wash., on the 29th and raising the backwater at Portland to the flood stage of 18 feet on June 3.

Following this warm period record-breaking rains fell in the Willamette Valley, causing higher stages in the Willamette River and its tributaries than had ever been recorded in June. Shortly after this there were very heavy rains in northern Idaho, causing a rapid rise in the Clearwater. Almost immediately following these rains a prolonged hot spell set in, bringing temperatures above 100 over large areas.

This combination resulted in the highest summer stage at Portland since 1894, and the highest at any time since 1923. However, crest stages at many points on the Columbia were somewhat below those of 1928.

Forecasting was made quite difficult by the occurrence of heavy rains at a time when the water was already unusually high from melting snow, and by the breaking and submergence of many dikes, which enabled the water to spread over an unusually wide area. However, relatively little movable property was lost, and there was little spent for needless protection.

So much had been said about unusually deep snow in the mountains the public was generally anticipating a higher freshet than actually occurred. Much of the value of the service rendered by the Weater Bureau lay in preventing unnecessary alarm.

Except at Kelso, Wash., where the breaking of a dike on Coweman River resulted in the flooding of the southern portion of the city, damage was mostly confined to the flooding of farm and pasture lands.

The situation in Portland was greatly simplified by the protection afforded by the harbor wall and pumping system. Basements in the principal west-side business district, which heretofore had been generally flooded in high-water periods, were kept dry in this freshet.

Table of flood stages in July 1933

[All dates in July unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	Feet			Feet	
Santee: Rimini, S.C	12	1	2	12.4	2
		13	16	12.9	15
		22	24	13.5	24
Savannah: Ellenton, S.C	14	23	24	14.5	23
EAST GULF OF MEXICO DRAINAGE					
Pearl: Jackson, Miss	18	14	15	18.2	14
		17	18	18.9	18
MISSISSIPPI SYSTEM					
Ohio Basin					
Elk: Fayetteville, Tenn	14	14	15	14.2	14
Red Basin					
Sulphur: Ringo Crossing, Tex	20	20	20	21.6	20
		24	24	21.0	24
WEST GULF OF MEXICO DRAINAGE					
Sabine:					
Logansport, La	25	24	(1)	34.6	25
Bon Wier, Tex	21	27	(1)	22.6	31
Trinity: Dallas, Tex	28	31	(1)	30.7	31
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Columbia: Vancouver, Wash	15	May 28	21	25.5	June 19

[1] Continued into August.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, W. F. McDonald, in charge]

NORTH ATLANTIC OCEAN

By W. F. McDonald

Atmospheric pressure.—The Atlantic area of high pressure was well developed and very steadily maintained over middle latitudes in July 1933. Hence, average barometer values were slightly above normal over much of the ocean. The greatest excess, 0.10 inch, was around Madeira. A slight deficiency in average pressure was noted between Labrador and Iceland, and also over Antillean waters. (See table 1.)

The highest pressures occurred between the Azores and Ireland on the 4th, and from the Azores to Bermuda on the 9th. Outside the Tropics and beyond the influence of tropical disturbances, the lowest barometer reading reported by any ship, the British steamship *Montrose*, was 29.41 inches off the Strait of Belle Isle on the 30th.

The lowest barometer reading, 28.51 inches, was reported by the American steamship *Lena Luckenbach*, very near the center of a tropical disturbance in the Gulf of Mexico, on July 5.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, July 1933*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.69		30.12	24	29.33	2, 5
Reykjavik, Iceland	29.77	−0.07	29.99	6	29.45	12
Lerwick, Shetland Islands	29.88	+.08	30.38	5	29.41	12
Valencia, Ireland	30.03	+.05	30.58	4	29.50	13
Lisbon, Portugal	30.10	+.08	30.29	9	29.93	26
Madeira	30.15	+.10	30.40	8	29.95	26
Horta, Azores	30.32	+.05	30.50	9	30.00	5
Belle Isle, Newfoundland	29.85	−.02	30.16	12	29.40	7
Halifax, Nova Scotia	30.00	+.05	30.32	4	29.44	1
Nantucket	30.00	+.02	30.27	3	29.62	1
Hatteras	30.03	+.02	30.22	4	29.80	12
Bermuda	30.15	−.03	30.26	19	30.00	3
Turks Island	30.02	−.05	30.10	19	29.70	27
Key West	29.99	−.04	30.08	23	29.89	2
New Orleans	29.97	−.03	30.15	30	29.81	12
Cape Gracias, Nicaragua	29.88	−.02	29.96	21	29.80	26

NOTE.—All data based on a.m. observations only with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—The lack of any barometer report lower than 29.41 inches from a ship on the northern trans-Atlantic routes, and the fact that the lowest reading shown for the land stations in table 1, also was well above 29 inches, indicate the absence of deeply developed cyclonic areas on the Atlantic in higher latitudes.

Gales were encountered in places along the main steamer routes on about half the days of the month. Storminess was most widespread between the 3d and 6th, and again from the 25th to 30th, when gales at higher latitudes occurred coincidently with tropical storms that attained hurricane intensity.

A sharp disturbance of no great extent, and relatively short lived, arose near Cape Hatteras on the 3d, moved northeastward past Cape Cod on the 4th, and produced fresh to strong gales, rising at times to the force of a whole gale along its course. The German liner *Europa* reported the highest wind at force 11 (storm) near latitude 40° N., longitude 68° W., on the 4th. This storm is shown on chart VIII.

Another disturbance of similarly brief history arose toward the end of the month in mid-Atlantic east of Bermuda, and caused strong gales on the 25th and 26th, as reported by the Dutch steamship *Barneveld* and the American steamship *Gateway City* and recorded in the accompanying table of gales and storms. The barometer did not fall below 29.76 inches, and this disturbance failed, after 2 days, to develop any further strength.

Fresh to whole gales occurred at widely separated intervals between the 6th and 30th on the northeastern Atlantic north of the 40th parallel and east of the 45th meridian. The major source of energy appears to have been the steady, rather strong, barometric gradient northward from the Azores HIGH, rather than the passage of any fully developed cyclonic area across the region of the gales.

Tropical disturbances.—Four disturbances of tropical origin affected the West Indies and Gulf of Mexico in July 1933. These are described at some length elsewhere in the present issue of the REVIEW.

Only two of these storms attained hurricane intensity, as reported by ships at sea. They are represented on charts VIII and XI, herewith. In the first instance, the American steamship *Lena Luckenbach*, en route from New Orleans to the Panama Canal, was at 3 a.m. on July 5, close to the center of a disturbance that had begun, over a week before, near Trinidad and, at the time of encounter, was progressing almost due westward across the middle Gulf of Mexico. It passed into Mexico near the Rio Grande the next day. The barometer on the *Lena Luckenbach* dropped to 28.51. The wind reached full hurricane intensity for a short time, and at the height of the storm shifted from north through west to south.

Minor disturbances passed from the vicinity of St. Kitts to Vera Cruz, between July 14th and 19th; and from near Progreso, Mexico, to Matagorda Bay, between July 21st and 23d.

The last tropical storm of the month, originated near Antigua on the 25th, moved almost due northwestward over the Bahamas, then turned westward into the Gulf of Mexico which it entered on the last day of the month and thence moved on slowly westward to the Rio Grande during the first five days of August. Nothing beyond moderate to fresh gales was reported from ships along the track until the storm reached the Bahamas, when, on the 28th, the Norwegian steamer *Noreg* recorded a southeast wind of force 11, a short distance east of Eleuthera Island. Strong gales to storm winds were reported, in the two days that followed, over the heavily traveled Gulf Stream route east of the Florida Peninsula, and on the 30th, during early morning hours, the American steamship *El Almirante* experienced a southeast hurricane, about 40 miles east of Jupiter Inlet.

The further history of this storm in the Gulf of Mexico will be briefly reported in next month's issue.

Trade winds of the Caribbean.—The trades of the western Caribbean were considerably intensified between July 8 and 10, rising to force 7 over a wide area, and attaining gale force (8) on the 9th near Old Providence Island. No center of disturbance appeared.

Fog.—Fog frequency was about normal, with the greatest prevalence between the Grand Banks and the American coast north of Cape Hatteras, where fog occurred on 10 to 20 days during the month. The frequency diminished eastward to only 2 to 4 days over the waters off the European coast.

Trans-Atlantic aviation.—Two flights across the Atlantic were successfully accomplished in July 1933. The

first was the westward passage, from Reykjavik, Iceland, to Cartwright, Labrador, of 24 Italian seaplanes manned by more than 100 officers and men commanded by General Italo Balbo. Chart IX, for July 12, depicts the weather conditions attending this largest undertaking in the annals of ocean aviation.

A few days later, Mr. Wiley Post, American pilot, set out from New York on the trans-Atlantic leg of his solo flight around the world. He landed safely in Berlin within 26 hours after take-off, thus setting a speed and distance record for the crossing. Chart X reproduces the synoptic map of July 15, in connection with Post's flight.

OCEAN GALES AND STORMS, JULY 1933

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Dakotian, Br.S.S.	Liverpool	Boston	47 49 N	50 25 W	July 1	Mdt. July 1.	July 2	29.27	SW	SW, 9	N	SW, 9	SW-W.
Santa Elisa, Am. S.S.	Cristobal	Habana	23 00 N	84 03 W	July 2	4a, 3	July 3	29.45	NNE		SSE	SE, 9	E-SE.
Carrillo, Am. S.S.	New Orleans	do	24 20 N	84 42 W	July 3	Noon, 3	do	29.59	E	ESE, 9	S	ESE, 9	E-ESE.
Fernbrook, Nor. M.S.	Colon	Baltimore	36 03 N	75 23 W	do	8a, 3	do	29.86	NE	SW, 4	NE	NE, 8	SW-W-NE.
John D. Archbold, Am. S.S.	Corpus Christi.	New York	24 24 N	88 00 W	July 4	Noon, 4.	July 4	29.28	NE		SSE	W, 10	W-SW.
Sylven Arrow, Am.S.S.	Beaumont	do	25 25 N	88 20 W	do	3p, 4	July 5	29.13	NNE	WNW, 11	SE	W, 11	NNW-SW.
Europa, Ger.S.S.	New York	Cherbourg	39 42 N	67 55 W	do	2p, 4	July 4	29.57	NNE	NE, 11	SSE	NNE, 11	NE-SE.
Gripsholm, Swed.M.S.	do	Gothenburg	40 40 N	67 55 W	do	4p, 4	do	29.70	NE	NE, 10	E	NE, 10	
Geo. H. Jones, Am.S.S.	New Orleans	New York	25 20 N	90 30 W	do	1a, 5	July 5	28.66	NNW	SE, 11	SE	NW-SE, 11.	WNW-SE.
Lena Luckenbach, Am. S.S.	do	Panama	25 32 N	90 40 W	do	3a, 5	do	28.51	NE		SE	NW, 12	N-W-S.
E. M. Clark, Am.S.S.	New York	CorpusChristi	24 36 N	94 51 W	July 3	3a, 6	July 6	29.41	NNE	SSW, 10	E	SW, 10	SW-SSW-S.
Nashaba, Am.S.S.	Antwerp	Tampa	44 30 N	17 30 W	July 5	10a, 6	do	29.50	S	W, 10	W	W, 10	Steady.
Adria, Ger.S.S.	Las Piedras	Dundee	45 18 N	42 36 W	July 7	4a, 8	July 9	29.97	SSW	SW, 7	WNW	SW, 8	SSW-SW-WNW.
Lena Luckenbach, Am. S.S.	New Orleans	Panama	13 32 N	80 32 W	July 9	2a, 9	do	29.83	E	E, 7	E	E, 8	Steady.
Black Falcon, Am.S.S.	Antwerp	New York	46 15 N	40 50 W	July 11	9p, 11	July 12	30.00	WSW	WSW, 7	W	W, 8	WSW-W.
Jean Jadot, Belg.S.S.	New York	Antwerp	48 10 N	29 08 W	do	8p, 12	July 13	29.94	WSW	WNW, 9	NW	NW, 9	W-WNW-NW.
Katendrecht, Du.M.S.	Rouen	Philadelphia	49 20 N	22 16 W	July 12	8p, 12	do	29.71	W	W, 7	WNW	W, 8	Steady.
Statendam, Du.S.S.	Rotterdam	New York	49 59 N	20 14 W	July 14	2p, 14	July 14	29.79	W	W, 8	NW	—, 8	W-WNW-NW.
Dresden, Ger.S.S.	Galway	do	51 12 N	25 54 W	July 18	5a, 18	July 18	29.46	SSE	W, 8	WNW	W, 8	SSW-W.
Daytonian, Br.S.S.	Guadeloupe	Havre	17 37 N	60 47 W	July 25	11a, 25	July 25	29.87	NE	NE, —	E	E, 9	NE-ENE-E.
Barneveld, Du.S.S.	Caracas	Liverpool	32 36 N	53 04 W	July 24	8a, 25	do	29.76	N	SSE, 9	SE	SSE, 9	None.
Gonzenheim, Ger.S.S.	Antwerp	Botwood	51 56 N	19 26 W	July 25	2p, 25	do	29.38	SW	NW, 8	NW	NW, 9	SE-NW.
Gateway City, Am.S.S.	London	Panama City, Fla.	34 02 N	51 05 W	do	3a, 26	July 26	29.84	SSE	SSW, 8	WSW	SSW, 8	SSE-SSW-SW.
Emilia, Am.S.S.	New York	San Juan	[1]21 00 N	65 30 W	July 26	Mdt., 26	do	29.97	ENE	SE, 6	SE	E, 8	Steady.
Noreg, Nor.S.S.	Bordeaux	Aruba	25 02 N	75 18 W	July 28	10a., 28	July 29	29.58	E	SE, —	SE	SE, 11	
Gulflight, Am.S.S.	New York	Port Arthur	28 20 N	77 30 W	July 29	11p., 29	July 30	30.02	E	ESE, 7	SE	E., 8	E-SE.
New York, Ger.S.S.	Cherbourg	New York	49 54 N	8 12 W	do	4a., 29	do	29.84	S	S, 4	NW	W, 8	SW-W.
Saccarappa, Am.S.S.	Antwerp	Charleston	50 15 N	37 00 W	do	11a., 29	July 29	29.73	NE	N, 7	N	N, 8	NE-N.
President Harding, Am. S.S.	Cobh	New York	50 42 N	22 00 W	July 30	5a., 30	July 30	29.53	S	SW, 9	NW	WNW, 10.	S-WSW.
Peten, Am.S.S.	New York	Habana	26 46 N	79 21 W	July 29	2a., 30	do	29.64	E	Var., 2	WSW	SW, 10	NE-SW.
El Almirante, Am.S.S.	Galveston	Boston	27 03 N	79 35 W	July 30	4a., 30	do	29.46	W	SE, 12	SE	SE, 12	W-SE.
Jean Jadot, Belg.S.S.	Antwerp	New York	49 35 N	18 53 W	do	6a., 30	do	29.80	SSW	SSW, 6	NNW	WNW, 9	W-NW.
NORTH PACIFIC OCEAN													
Brandywine, Am.S.S.	Los Angeles	Portland, Oreg.	40 12 N	124 44 W	July 5	11p., 5	July 7	29.86	NW	NW, 7	NW	NW, 8	NW-N.
Toba Maru, Jap.S.S.	Balboa	Los Angeles	15 40 N	97 55 W	July 7	2p., 7	July 8	[2]29.70	ESE	E, 7	SSW	S, 7	Var.
City of Elwood, Am.S.S.	do	do	16 25 N	100 36 W	July 8	4a., 8	do	29.68	SSW	Var., 8	SSW	SSW, 9	Var.
Memphis City, Am.S.S.	Los Angeles	Balboa	[1]17 30 N	102 00 W	do	5p., 8	do	29.56	NNE	NNE, —	SW	NNE, 8	NNE-SW.
Hofuku Maru, Jap.S.S.	do	do	17 13 N	101 15 W	do	7a., 8	do	[2]29.60	SSW	SSW, 8	SE	SSW, 9	SSW-SSE.
Neches, U.S.S.	San Diego	do	7 55 N	83 57 W	July 22	4a., 22	July 22	29.80	SSW	W, 4	SSW	SE, 12	SE-S.
Drechtdyk, Du.S.S.	Los Angeles	do	16 12 N	99 44 W	July 29	1p., 29	July 29	29.80	NE	ESE, 7	SSE	E, 8	E-SE.
Holystone, Br.S.S.	Panama	Vancouver	16 33 N	100 52 W	do	4p., 29	do	29.62	NNE	ESE, 9	WSW	WSW, 12	ESE-WSW.
Golden Star, Am.S.S.	Philippines	San Francisco	18 17 N	135 05 E	July 28	do	July 30	29.52	E	ESE, —	S	E, 10	E-ESE-SE.
Michigan, Am.S.S.	do	do	20 30 N	132 12 E	July 30	Mdt., 30	July 31	[2]28.92	ENE	ESE, 12	SSW	E, 12	Do.

[1] Position approximate.

[2] Barometer uncorrected.

NORTH PACIFIC OCEAN, JULY 1933

By WILLIS E. HURD

Atmospheric pressure.—A great and practically unbroken high-pressure area covered the major part of the North Pacific Ocean during July 1933. Pressures were above normal from the Bering Sea southward to Honolulu and Midway Island, and along the northern coast of the United States, and were below normal from California southward, and in the extreme southwestern part of the ocean. Some unimportant depressions appeared in northern latitudes of the Pacific, but the Aleutian LOW was largely indicated as having receded to the Arctic Ocean (Point Barrow, 29.76 inches).

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, July 1933, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.76	−0.16	30.16	14	29.34	4
Dutch Harbor	29.98	+.04	30.44	1	29.52	27, 29
St. Paul	29.96	+.12	30.34	14	29.34	28
Kodiak	29.92	−.02	30.18	14	29.60	9
Juneau	30.01	−.04	30.37	14	29.55	1
Tatoosh Island	30.12	+.07	30.36	4	29.73	1
San Francisco	29.89	−.06	30.11	3	29.73	27
Mazatlan	29.84	−.09	29.94	14	29.66	8
Honolulu	30.07	+.05	30.16	1	29.97	22
Midway Island	30.19	+.08	30.28	1	30.06	31
Guam	29.79	−.05	29.86	16	29.70	3
Manila	29.75	−.05	29.86	1	29.58	28
Naha	29.76	+.04	29.92	6	29.22	31
Chichishima	29.89	+.04	30.08	25	29.74	9
Nemuro	29.88		30.12	30	29.46	23

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales.—No cyclones crossed the North Pacific high pressure region this month, and no gales were reported except from the American coastal region and the Far East. A fresh northwest gale was experienced at sea south of Eureka on the 5th; otherwise, all gales were of tropical character.

Closely following the disintegration of a West Indian hurricane that crossed the east Mexican coast on the 6th, moderate southerly gales occurred in the Pacific midway between Salina Cruz and Acapulco on the 7th, and fresh to strong southwesterly to rapidly shifting gales of cyclonic nature, with barometer depressed about 0.20 inch, were reported near Acapulco on the 8th.

On the 29th, in the same locality (16°35′ N., 100°52′ W.), the British steamship *Holystone* reported a disturbance of cyclonic characteristics, accompanied by much thunder and lightning, with a maximum velocity of force 12 from west-southwest in a gust at 4:20 p.m.

A violent gale (SE., force 12) of brief duration, accompanied by a pressure drop of 0.06 inch, was reported by the U.S.S. *Naches* on the 22d off the extreme southern coast of Costa Rica (7°55′ N., 83°57′ W.). The ship reported "passing through the inner circle of a tropical disturbance." Heavy rain and thunder squalls were noted by other ships in this neighborhood on the 20th to 22d.

Typhoon of the Far East.—There were some evidences of cyclonic activity on several occasions in the Far Eastern tropics during July, but so far as at present indicated only one of these disturbances developed any marked intensity. This was a typhoon which originated near Guam on the 24th. On the 31st, with greatly increased intensity, it was over the Nansei Islands, approaching Japan. The American steamship *Golden Star* encountered this typhoon on the 28th to 30th, with maximum wind velocity of force 10 from the east on the 29th, and lowest barometer 29.52, at 18°17′ N., 135°05′ E. The American steamship *Michigan* encountered full hurricane velocities from east and southeast on the night of the 30th–31st, near 20°30′ N., 132°12′ E., with uncorrected barometer down to 28.92 inches. The typhoon at that time was reported as developing and moving northeast with a speed of 30 kilometers per hour.

Fog.—Fog was most frequent off the coast of Lower California, where it was reported on 11 days. But about 10 days with fog were noted along the entire northward coast to the mouth of the Columbia River. Along the northern steamship routes some 20 to 30 percent, or more, of days had fog from 150° W. to 150° E.

TYPHOONS OF JUNE AND JULY 1933 IN EASTERN SEAS

By Rev. C. E. Deppermann, S.J.

[Assistant Director, Philippine Weather Bureau, Manila]

The following remarks regarding depressions of typhoon character that came in rapid succession beginning June 27, 1933, involve the use of ideas from the Norwegian system of frontal analysis. I find in them the key to the solution of Far Eastern weather problems; the only trouble is that very often, due to lack of observations from ships on the Pacific and from Central Asia, the key cannot be used with precision.

There were no typhoons until near the end of June, when a weak disturbance began the season. Thereafter followed four others. These are noted individually as follows, the dates being those on which the depressions could be first definitely identified:

(1) *June 27.*—This originated east of Hainan in the "intertropical front", i.e., the front between the trade wind and the so-called "southwest monsoon" (southern hemisphere air). The trade wind to the north was going from east to west, blocking the path of the southwest monsoon. The mountain ranges along the eastern coast of Indo-China helped to perpetuate the cyclonic motion once it started. This typhoon traveled slowly north and when it reached the interior of southern China on June 30 dissipated; at the same time a depression started west of Amoy, giving the false impression that the typhoon had quickly gone north to Shanghai and Korea.

(2) *July 16.*—This typhoon was first discovered near 17° N., 134° E., but it is probable that it started much farther east on the intertropical front, between Guam and the Bonins. It traveled westward along the front until the end of the 17th, when it turned northward around the trade-wind HIGH until it came to the Eastern Sea, during the 20th, about which time the storm had much occluded. There it broke connections with the intertropical and joined the polar front, continuing along the latter toward the Aleutian Islands until off our maps, on the 24th.

(3) *July 19.*—This typhoon was first observed when it came into the region of our maps around Guam, also on the intertropical front. Its later course was almost identical with the preceding typhoon, passing into the Eastern Sea on the 24th and thence northeastward beyond the range of the maps, on the 26th. Neither of these typhoons (2 and 3) was of more than moderate intensity.

(4) *July 27.*—Due to lack of observations this can at present be traced no farther eastward toward its origin than the 127th meridian at latitude 17° N. It undoubtedly started beyond that point on the intertropical front, which it followed until disappearance over northern Indo-China on the 31st. This front, after the preceding typhoon (3), settled down to the line between Formosa and North Luzon, over Hainan, from the direction of the Carolines. This depression was small when it reached the Philippines, but increased a bit in intensity as it got into the China Sea.

(5) *July 26* (*Guam*).—This began about 400 miles east of Yap and about due south of Guam, on the same front, and followed the same track as typhoon (4) until near the Philippines. Here an interesting change of direction occurred. Although the intertropical front still went west to Hainan where the preceding depression was located, this typhoon went north after the 30th. Why? Most probably the *main* stream of the trade wind (in the upper air) went north and not west at the place of departure from the surface front. Typhoons seem to follow the direction of the air stream of the medium upper levels.

This typhoon slackened its pace and deepened very much as it reached the Loo-Choos on August 1. In the Eastern Sea it broke again with the southwest monsoon and entered the polar front circulation. There was much damage in Korea, over which the storm passed on August 4. Thereafter, in the Japan Sea, something peculiar seems to have happened, and it is possible that the typhoon split, one part going on northeastward, and the other re-forming to the east of central Japan and then going east. We must await further information on this situation.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July 1933

[For description of tables and charts, see REVIEW, January, p. 37]

[Compiled by Annie E. Small]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	79.4	−0.8	Madison	105	3	St. Bernard	52	6	7.38	+1.97	Robertsdale	18.49	Benton	2.36
Arizona	84.1	+2.4	3 stations	120	[1] 26	Big Spring Ranger Station.	39	1	1.87	−.26	Williams	5.48	5 stations	.00
Arkansas	81.4	+1.1	2 stations	109	[1] 10	Dutton	55	16	5.01	+1.15	Crossett	12.89	Ozark	1.16
California	74.8	+1.1	Greenland Ranch	127	[1] 26	2 stations	31	[1] 1	.04	−.03	South Lake	2.20	144 stations	.00
Colorado	70.0	+3.2	Las Animas	114	1	Pearl	24	[1] 1	1.82	−.44	Calhan	6.82	Bloom	.38
Florida	81.2	−.1	Lake Placid	105	9	Monticello	61	5	10.19	+3.05	West Palm Beach	23.28	Key West	3.30
Georgia	79.3	−.7	Hazlehurst	105	3	Clayton	45	5	5.95	+.24	Eastman	14.37	Athens	1.85
Idaho	70.3	+2.3	Orofino	115	24	Warren	24	1	.17	−.46	Prichard	1.06	15 stations	.00
Illinois	77.9	+1.7	Sparta	107	2	2 stations	49	[1] 17	2.54	−.75	Grand Chain	7.50	Decatur	.28
Indiana	77.0	+1.6	Edwardsport	108	2	Frankfort	46	12	2.56	−.80	Rome	8.31	Seymour	.42
Iowa	76.1	+1.8	Guthrie Center	105	11	Webster City	46	16	3.45	−.28	Marathon	11.13	Tracy	T
Kansas	81.4	+2.9	Lincoln	116	1	2 stations	48	27	2.80	−.54	Paola	6.56	Richfield	T
Kentucky	77.0	.0	Williamstown	106	22	do	47	5	6.05	+1.94	Mayfield	12.50	Grant	1.30
Louisiana	81.6	−.2	2 stations	104	[1] 3	Franklinton	60	[1] 8	11.55	+5.34	Shreveport	25.45	Port Eads	3.91
Maryland-Delaware	74.1	−1.1	Cumberland, Md	102	23	Oakland, Md	37	4	5.36	+1.12	Solomons, Md	8.45	Hancock (Tonoloway), Md.	2.65
Michigan	71.1	+2.4	Coldwater	106	23	Vanderbilt	30	4	1.98	−.87	Newberry	6.81	Frankfort	.13
Minnesota	73.0	+3.3	Beardsley	110	29	Two Harbors	38	5	2.53	−.85	Waseca	5.89	Leech Lake Dam	.45
Mississippi	80.7	−.3	2 stations	105	3	4 stations	59	[1] 7	7.36	+2.28	Collins	15.20	Holly Springs	2.63
Missouri	79.3	+1.7	Warsaw	108	2	Elsberry	49	17	2.49	−1.35	Sikeston	7.26	Milan	.12
Montana	70.0	+3.5	4 stations	110	[1] 25	Upper Yaak River	25	30	.49	−1.00	Fairview	2.79	Augusta	.00
Nebraska	77.6	+2.9	Fairbury	112	7	2 stations	43	23	2.94	−.40	Seward	8.95	Bridgeport	.25
Nevada	76.6	+4.3	Logandale	118	26	Zorra Vista Ranch	32	10	.34	−.03	Sharp	3.26	4 stations	.00
New England	68.5	−.5	Waterbury, Conn	102	31	2 stations	36	[1] 3	2.91	−.82	Dixville Notch, N.H	7.20	Burlington, Vt	.58
New Jersey	73.4	−.3	Newton	105	31	Long Valley	41	4	3.73	−1.06	Bridgeton	6.05	Newton	1.20
New Mexico	74.1	+1.9	Nara Visa	112	1	Therma (near)	32	[1] 28	2.28	−.34	Grahams Ranch	5.93	Doretta	.14
New York	71.3	+1.8	Scarsdale	103	31	Indian Lake	35	4	2.14	−1.78	Elmira	6.50	Stafford	.10
North Carolina	75.8	−1.1	Southern Pines	103	9	2 stations	36	5	5.52	−.25	Hatteras	13.59	Concord	1.79
North Dakota	71.9	+3.5	Bottineau	109	28	Powers Lake	36	31	2.00	−.42	Parshall	4.95	Alpha	.39
Ohio	74.7	+1.2	2 stations	106	[1] 22	Bellefontaine	42	5	2.47	−1.33	Middleport	6.33	Ellsworth	.82
Oklahoma	83.9	+2.5	Mutual	114	10	Goodwell	49	27	3.18	+.08	Durant	8.16	Carnegie	.73
Oregon	67.4	+1.0	Vale	109	25	5 stations	26	[1] 10	.13	−.28	Bend	1.18	38 stations	.00
Pennsylvania	72.5	+.5	Sharon	104	23	Mt. Pocono	35	4	4.26	−.03	Lancaster	9.13	Erie	1.12
South Carolina	78.8	−1.0	2 stations	103	[1] 2	Santuck	48	5	5.15	−.65	Conway	12.52	Ferguson	.45
South Dakota	77.5	+5.0	Kennebec	117	28	2 stations	41	23	2.34	−.29	Wagner	8.04	Dowling	.18
Tennessee	77.8	+.3	2 stations	104	[1] 1	Rugby	44	[1] 6	6.01	+1.58	Union City	11.78	Knoxville	3.08
Texas	84.1	+1.1	do	115	[1] 12	Alpine	53	26	4.15	+1.55	Bronson	20.28	Eden	.00
Utah	74.7	+3.1	St. George	110	[1] 13	Soldiers Summit	29	2	1.01	+.11	La Sal	4.20	3 stations	T
Virginia	74.6	−.7	Clarksville	104	2	Emory	40	5	5.44	+.99	Deerfield	8.94	Cape Henry	2.44
Washington	65.6	−.6	Mottinger	110	15	Mt. Baker Lodge	28	29	.50	−.15	Mt. Baker Lodge	2.98	4 stations	.00
West Virginia	72.6	+.4	New Martinsville	104	23	2 stations	36	4	5.21	+.64	Crawford	8.52	Ravenwood	1.94
Wisconsin	72.1	+2.3	High Falls	103	30	3 stations	35	16	3.00	−.61	2 stations	6.41	Breakwater	.58
Wyoming	69.3	+3.9	Barnum	108	18	2 stations	28	[1] 1	.64	−.68	Douglas	2.46	3 stations	.00
Alaska (June)	50.0	−2.8	Fairbanks (near)	89	22	Barrow	10	4	1.70	−.06	Mile Seven-Cordova	9.81	2 stations	T
Hawaii	72.8	−1.4	Waipahu	92	19	Volcano Observatory.	49	13	4.34	−1.35	Kawainui (upper)	29.61	13 stations	.00
Puerto Rico	79.0	+.4	San German	96	13	Guineo Reservoir	52	22	5.69	−1.04	Jajome Alta	12.40	Ensenada	.7

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, July 1933*

(Compiled by Annie E. Small)

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							**68.3**	**−0.6**										**79**	**1.90**	**−1.6**										**5.8**		
Eastport	76	67	85	29.94	30.02	+0.09	60.0	−0.4	81	1	68	47	5	52	27	56	54	87	1.30	−1.8	13	5,759	sw.	28	sw.	1	10	9	12	6.1	0.0	0.0
Greenville, Maine	1,070	6		28.86	30.01		62.8		83	6	73	37	3	53	38				3.87		16	3,031	se.	18		28	8	10	12		.0	.0
Portland, Maine	103	82	117	29.89	30.01	+.06	66.8	−1.3	91	1	74	54	4	60	28	60	57	76	2.51	−.7	12	5,534	s.	23	nw.	30	9	12	10	5.5	.0	.0
Concord	289	70	79	29.70	30.00	+.04	69.1	+.6	94	27	81	48	13	58	42				3.25	−.3	10	3,086	se.	22	ne.	5	12	12	7	5.1	.0	.0
Burlington	403	11	48	29.56	29.98	+.04	69.5	−.8	92	21	80	47	26	58	33				.58	−2.9	8	5,957	s.	21	se.	22	7	14	10	5.8	.0	.0
Northfield	876	12	60		30.00	+.06	66.8	+.9	91	23	80	42	26	53	39			74	.97	−2.6	11	5,220	s.	25	n.	28	2	21	8	6.4	.0	.0
Boston	125	106	165	29.87	30.00	+.04	70.8	−.9	98	30	79	52	5	62	31	63	59	70	2.63	−.9	10	5,932	sw.	28	ne.	5	8	13	10	5.7	.0	.0
Nantucket	12	14	90	29.98	30.00	+.02	65.9	−1.9	81	18	72	52	14	60	21	62	60	89	1.01	−1.9	7	10,868	sw.	59	ne.	4	7	11	13	6.3	.0	.0
Block Island	26	11	46	29.97	30.00	+.03	66.8	−1.6	82	30	72	54	14	61	17	64	62	89	1.16	−1.9	7	10,425	sw.	49	n.	5	8	13	10	5.7	.0	.0
Providence	160	215	251	29.83	30.00	+.03	71.0	−2.4	97	30	80	52	13	62	30	64	60	72	2.24	−1.0	9	6,820	s.	30	n.	5	12	9	10	5.1	.0	.0
Hartford	159	122		29.83	30.00	+.03	72.5	+.9	97	30	83	52	4	62	30				1.71	−2.7	9		sw.				11	7	13	5.5	.0	.0
New Haven	106	74	153	29.90	30.01	+.04	72.4	+.6	97	30	81	54	4	64	25	65	62	73	3.58	−.7	9	6,163	s.	31	ne.	5	8	11	12	6.2	.0	.0
Middle Atlantic States							**74.6**	**−0.4**										**73**	**4.19**	**−0.2**										**5.3**		
Albany	97	107	115	29.89	29.99	+.03	74.6	+2.0	100	30	86	54	15	64	30	65	60	66	1.83	−1.6	11	5,511	s.	24	e.	22	9	13	9	5.5	.0	.0
Binghamton	871	60	68	29.11	30.02	+.05	71.7	+1.7	96	31	84	47	4	59	33				5.23	+1.5	10	3,638	ne.	22	w.	22	7	17	7	5.5	.0	.0
New York	314	414	454	29.67	30.00	+.02	73.7	−.1	100	31	82	55	3	66	25	66	63	74	2.77	−1.5	7	8,232	sw.	56	n.	1	10	10	11	5.7	.0	.0
Bellefonte	1,050	5	42	28.93	30.02		70.2		95	31	84	46	4	57	37	64	60	73	2.94		7		w.				12	13	6	4.7	.0	.0
Harrisburg	374	94	104	29.62	30.00	+.02	75.0	+.2	98	31	85	54	4	65	27	66	61	66	4.64	+.8	9	4,774	w.	34	nw.	2	11	14	6	4.9	.0	.0
Philadelphia	114	123	367	29.90	30.02	+.04	76.6	+.4	99	31	86	54	3	68	24	67	63	68	4.70	+.6	8	8,276	sw.	36	ne.	3	12	10	9	5.2	.0	.0
Reading	323	283	304	29.67	30.01		74.4	−1.1	97	31	84	50	4	65	29	66	62	69	4.69	+.4	9	6,621	nw.	41	e.	2	9	14	8	5.3	.0	.0
Scranton	805	72	104	29.17	30.01	+.03	72.8	+1.1	97	31	84	49	4	61	32	64	60	67	6.71	+2.7	8	4,288	sw.	26	nw.	1	8	19	4	4.8	.0	.0
Atlantic City	52	37	172	29.96	30.01	+.03	72.4	+.3	94	31	78	54	4	66	22	67	65	83	2.80	−1.1	10	10,488	s.	50	ne.	3	6	9	16	6.9	.0	.0
Sandy Hook	22	10	55	29.98	30.00		73.4		99	31	80	54	3	66	25	67	65	80	2.28	−2.8	10	8,458	sw.	50	ne.	1	11	8	12	5.0	.0	.0
Trenton	190	159	183	29.81	30.01		74.1	−.4	98	31	84	52	3	64	26	67	63	72	3.42	−.5	10	5,960	s.	24	ne.	3	10	13	8	5.2	.0	.0
Baltimore	123	100	215	29.89	30.01	+.03	77.2	.0	100	31	86	54	4	69	27	68	64	66	3.90	−.7	7	7,031	sw.	33	nw.	9	14	8	9	5.0	.0	.0
Washington	112	62	85	29.90	30.01	+.01	76.1	−.7	99	1	85	52	4	67	29	68	65	71	6.71	+2.0	10	4,342	s.	31	nw.	2	14	7	10	5.0	.0	.0
Cape Henry	18	8	54	29.99	30.01		75.0	−2.5	94	8	81	60	4	69	27	70	68	81	2.44	−2.9	12	7,679	sw.	44	ne.	3	10	8	13	6.0	.0	.0
Lynchburg	686	153	188	29.30	30.03	+.02	76.5	−1.0	99	24	88	51	4	65	33	68	64	71	4.30	+.1	13	3,489	e.	30	ne.	3	14	12	5	4.1	.0	.0
Norfolk	91	170	205	29.94	30.03	+.03	76.8	−1.9	96	31	85	61	5	69	25	70	67	79	5.26	−.5	14	7,361	s.	32	ne.	3	9	5	17	6.4	.0	.0
Richmond	144	11	52	29.88	30.03	+.02	76.2	−2.3	97	1	86	52	4	66	29	69	67	77	4.59	−.1	11	4,700	sw.	26	e.	3	12	9	10	4.9	.0	.0
Wytheville	2,304	49	55	27.71	30.01	.00	71.2	−1.4	92	24	82	45	5	60	34	64	61	75	5.01	+1.0	13	3,688	w.	18	e.	3	9	12	10	5.4	.0	.0
South Atlantic States							**78.3**	**−0.8**										**77**	**5.95**	**+0.1**										**5.8**		
Asheville	2,253	89	104	27.76	30.04	+.02	73.4	+1.7	91	2	85	46	5	62	35	65	62	77	3.50	−.8	14	4,381	s.	30	e.	3	6	12	13	6.1	.0	.0
Charlotte	779	244	267	29.22	30.04	+.02	77.6	−.8	94	2	87	55	4	68	28	68	64	71	2.08	−3.0	10	7,049	sw.	31	ne.	3	8	15	8	5.3	.0	.0
Greensboro	886	6	56	29.10	30.04		76.6		97	2	88	48	5	65	37	68	65	73	3.81		11	5,033	sw.	33	ne.	3	9	12	10	5.6	.0	.0
Hatteras	11	5	50	30.01	30.02	+.01	76.4	−1.8	88	27	81	56	5	72	25	73	71	84	13.59	+9.1	14	8,919	sw.	32	ne.	3	10	10	11	5.6	.0	.0
Raleigh	376	103	146	29.64	30.02	.00	77.9	−.9	98	1	88	54	4	68	28	69	66	72	2.12	−3.3	8	5,653	sw.	28	ne.	3	9	11	11	5.7	.0	.0
Wilmington	72	73	106	29.97	30.04	+.03	77.7	−1.4	92	1	86	58	5	70	29	72	70	83	7.63	+.5	18	6,344	sw.	30	nw.	3	10	11	10	5.5	.0	.0
Charleston	48	11	92	29.99	30.04	+.01	80.3	−1.1	97	3	86	61	4	74	27	75	73	81	8.12	+1.2	12	7,251	sw.	30	ne.	3	8	12	11	5.9	.0	.0
Columbia, S.C.	351	41	57	29.66	30.03	+.01	79.4	−1.5	96	1	89	59	5	70	30	71	68	75	2.92	−2.4	16	4,889	sw.	25	nw.	2	11	9	11	5.4	.0	.0
Greenville, S.C.	1,039	139	146	28.96	30.03		77.2	+.3	96	2	86	58	4	68	31	69	65	73	3.07	−2.3	12	5,512	s.	34	ne.	3	7	15	9	5.6	.0	.0
Augusta	182	62	77	29.83	30.02	.00	80.4	−.9	100	3	90	61	4	71	35	72	69	75	4.82	−.6	13	4,210	s.	32	ne.	3	4	16	11	5.9	.0	.0
Savannah	65	73	152	29.97	30.04	+.01	80.3	−1.2	97	3	88	61	4	72	21	74	72	83	6.78	+.1	20	6,654	sw.	27	nw.	17	11	8	12	6.0	.0	.0
Jacksonville	43	209	245	29.98	30.03	.00	81.0	−1.1	95	2	88	65	14	74	20	74	72	81	10.80	+4.1	19	7,706	s.	32	w.	14	3	15	13	6.4	.0	.0
Florida Peninsula							**82.4**	**+0.5**										**78**	**7.75**	**+2.2**										**7.1**		
Key West	22	10	64	29.97	29.99	−.04	84.0	+.5	94	30	89	75	2	79	16	77	75	76	3.30	.0	12	7,081	se.	24	se.	3	3	13	15	6.8	.0	.0
Miami	25	124	168	30.00	30.03	−.01	81.5	+.5	89	15	86	69	24	77	18	76	73	77	7.64	+2.2	24	7,445	se.	32	s.	31	0	10	21	8.2	.0	.0
Tampa	35	88	197	29.98	30.01	−.03	81.8	+.6	93	1	89	69	7	74	21	74	72	81	12.32	+4.4	17	7,402	e.	39	e.	31	4	17	10	6.2	.0	.0
Titusville	44	5	25	29.97	30.02		81.0		96	16	90	69	25	73	24				8.52		18		sw.								.0	.01
East Gulf States							**79.8**	**−0.9**										**80**	**7.50**	**+1.8**										**6.6**		
Atlanta	1,173	190	198	28.82	30.04	+.02	77.4	−.7	94	3	86	59	5	69	28	69	66	74	3.22	−1.4	17	5,604	w.	38	sw.	27	4	14	13	6.3	.0	.0
Macon	370	76	84	29.64	30.03	+.01	78.8	−2.4	97	3	88	60	6	70	28	71	69	76	4.85	+.1	14	4,561	s.	25	se.	3	4	13	14	6.6	.0	.0
Thomasville	273	49	103	29.73	30.02	−.01	80.4	−1.4	97	3	90	66	6	71	25	73	72	83	7.82	+1.1	17	4,988	se.	30	e.	31	2	17	12	6.9	.0	.0
Apalachicola	36	11	51	29.97	30.01		81.2		90	9	87	71	5	75	16	76	74	80	8.72	+1.0	14	6,246	s.	32	e.	31	12	9	10	5.3	.0	.0
Pensacola	56	149	185	29.94	30.00	−.01	79.6	−1.4	95	12	85	69	14	74	19	76	74	84	12.47	+5.7	18	8,085	s.	37	w.	15	8	13	10	5.9	.0	.0
Anniston	741	9	57				78.6	+.7	96	3	89	56	6	68	34				6.71	+1.5	12		s.				6	15	10		.0	.0
Birmingham	700	11	48	29.26	30.01	.00	79.6	−.6	96	3	89	64	6	70	26	71	68	77	4.64	−.5	15	4,689	s.	23	s.	26	4	15	12	6.3	.0	.0
Mobile	57	125	161	29.92	29.98	−.03	81.0	−.4	96	12	88	70	5	74	21	75	73	82	11.75	+4.9	17	6,021	s.	35	sw.	26	5	9	17	7.0	.0	.0
Montgomery	218	92	105	29.77	30.02	.00	80.2	−1.5	96	30	88	66	26	72	26	72	69	78	3.86	−1.0	15	4,644	e.	32	s.	26	4	11	16	6.8	.0	.0
Meridian	375	87	95	29.60	29.98	−.04	79.2	−1.2	95	31	87	65	7	71	24	73	71	82	11.63	+6.7	15	3,754	e.	24	w.	2	5	11	15	6.7	.0	.0
Vicksburg	247	65	73	29.71	29.97	−.03	80.6	−.7	95	3	88	69	18	73	22	74	72	80	7.06	+2.5	13	5,113	sw.	18	w.	13	2	12	17	7.5	.0	.0
New Orleans	53	76	84	29.92	29.97	−.03	82.3	−.1	95	31	88	73	26	76	21	76	74	81	7.32	+1.0	19	5,104	sw.	21	ne.	1	3	11	17	7.2	.0	.0
West Gulf States							**83.1**	**+0.5**										**73**	**7.10**	**+4.0**										**5.4**		
Shreveport	249	92	227	29.67	29.93	−.05	82.4	−.8	103	11	91	68	25	74	28	74	72	78	25.45	+21.9	17	7,375	se.	36	n.	4	6	17	8	6.0	.0	.0
Bentonville	1,303	11	44	28.60	29.92	−.05	79.8	+1.3	101	2	90	62	16	69	33				4.57		10	3,923	s.	17	se.	3	11	9	11		.0	.0
Fort Smith	457	79	94	29.46	29.92	−.05	84.1	+2.6	104	10	94	69	25	74	27	72	68	64	2.95	−.4	10	5,363	e.	27	s.	13	5	14	12	6.2	.0	.0
Little Rock	357	94	102	29.59	29.95	−.04	81.0	+.1	101	3	89	67	27	73	23	72	68	71	3.97	+.5	12	5,443	e.	20	ne.	26	10	5	16	6.3	.0	.0
Austin	605	136	148	29.28	29.91		84.9	+.9	104	12	95	68	16	75	27	74	69	65	7.16	+4.8	8	5,987	se.	32	ne.	16	12	13	6	4.8	.0	.0
Brownsville	57	88	96	29.82	29.88		82.5	−1.1	93	22	89	70	26	76	19	76	75	83	4.50	+2.5	11	8,083	se.	35	ne.	6	8	15	8	5.3	.0	.0
Corpus Christi	20	11	78	29.91	29.93	−.03	83.2	+.5	94	24	89	72	29	77	17	77	75	82	2.54	+1.0	7	8,418	s.	30	ne.	6	9	16	6	5.5	.0	.0
Dallas	512	220	227	29.38	29.91		83.6		104	11	92	69	29	75	29				3.49	+.6	6	8,357	se.	38	ne.	4	15	9	7	4.3	.0	.0
Fort Worth	670	106	114	29.20	29.90	−.06	85.4	+1.8	106	11	95	68	27	76	26	72	66	59	5.70	+3.1	3	6,925	se.	30	e.	30	14	10	7	4.6	.0	.0
Galveston	54	106	114	29.88	29.94	−.04	82.6	−.8	93	4	87	71	28	78	14	77	75	82	8.66	+5.0	9	8,709	s.	35	s.	23	9	16	6	5.4	.0	.0
Houston	138	292	314	29.79	29.93		82.6	−1.1	98	4	90	71	26	75	22				7.97	+4.0	10	8,040	s.	35	n.	27	6	15	10	6.0	.0	.0
Palestine	510	64	72	29.41	29.93	−.04	82.6	+.4	102	4	92	68	27	74	25	74	70	74	2.66	.0	8	5,720	s.	32	s.	15	5	19	7	5.8	.0	.0
Port Arthur	34	58	66	29.90	29.94		82.6		97	4	89	69	28	76	20	76	74	82	18.21	+11.3	12	6,829	s.	26	se.	23	9	16	6	5.3	.0	.0
San Antonio	693	242	301	29.19	29.88	−.07	85.0	+1.2	103	12	95	70	28	75	29	73	68	65	1.98	−.2	5	8,224	se.	30	se.	29	8	18	5	5.0	.0	.0
Taylor	571	38	51	29.34	29.93	−.03	84.8	+2.1	105	12	95	70	28	74	27				4.09	+1.8	7	6,738	s	24	s.	30	13	14	4	4.5	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, July 1933*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
							71.1	**+0.6**										**65**	**4.05**	**+0.2**										**5.2**		
Chattanooga	762	190	215	29.23	30.02	.00	78.6	+.2	97	2	88	62	6	69	27	69	65	69	7.28	+3.0	11	4,626	se.	38	nw.	3	4	17	10	5.9	.0	.0
Knoxville	995	79	97	28.98	30.01	−.01	79.4	+2.3	97	22	90	61	6	69	29	69	64	66	3.08	−1.3	14	4,264	sw.	27	se.	23	8	14	9	5.3	.0	.0
Memphis	399	78	86	29.55	29.97	−.03	81.2	+.5	97	3	88	70	26	74	19	72	68	68	6.15	+3.0	5	4,495	sw.	15	nw.	3	9	10	12	5.9	.0	.0
Nashville	546	168	191	29.44	30.01	.00	78.6	−.5	97	2	88	62	6	69	29	70	66	69	5.37	+1.5	10	5,377	sw.	25	ne.	3	7	13	11	5.8	.0	.0
Lexington	989	193	230	29.02	30.04	+.03	75.7	−.2	96	22	84	55	4	67	25				4.72	+1.1	10	5,657	e.	26	e.	4	16	8	7	4.0	.0	.0
Louisville	525	188	234	29.45	30.02	+.02	77.9	−.7	98	22	87	60	4	69	28	68	62	64	3.98	+.3	10	6,383	s.	32	n.	14	9	8	14	5.6	.0	.0
Evansville	431	76	116	29.53	29.99	−.01	80.0	+1.3	101	1	89	64	4	71	25	69	64	62	5.61	+2.2	6	5,806	sw.	22	s.	23	15	8	8	4.6	.0	.0
Indianapolis	822	194	230	29.14	30.00	+.01	77.8	+2.1	99	22	88	58	5	68	31	66	59	57	5.85	+2.5	9	6,991	sw.	34	sw.	1	13	8	10	5.2	.0	.0
Terre Haute	575	96	129	29.39	29.99		79.2		100	2	90	56	5	69	33	67	60	56	.72	−2.5	9	6,341	ne.	23	sw.	2	14	11	6	4.0	.0	.0
Cincinnati	627	11	51	29.35	30.02	+.02	76.5	+1.4	101	22	88	56	4	66	33	67	62	66	1.50	−1.8	8	4,333	sw.	21	ne.	2	13	6	12	5.3	.0	.0
Columbus	822	216	230	29.16	30.02	+.02	76.5	+1.6	99	23	87	59	4	66	27	65	59	60	.85	−2.7	5	6,390	ne.	31	w.	24	13	11	7	4.7	.0	.0
Elkins	1,947	59	67	28.07	30.06	+.05	69.4	−.9	92	23	81	41	4	58	35	63	61	81	4.92	−.5	13	3,265	se.	18	se.	24	7	13	11	5.9	.0	.0
Parkersburg	637	77	82	29.41	30.06	+.05	75.2	−.2	98	22	85	54	4	65	32	68	64	72	3.51	−.8	9	3,695	se.	38	nw.	1	11	14	6	4.9	.0	.0
Pittsburgh	842	353	410	29.15	30.03	+.03	75.0	+.4	98	23	85	54	4	65	30	64	58	61	3.21	−.8	11	5,938	sw.	41	nw.	22	13	9	9	5.0	.0	.0
Lower Lake Region							**73.7**	**+2.3**										**61**	**1.68**	**−1.6**										**4.2**		
Buffalo	767	243	280	29.19	30.00	+.03	71.6	+1.8	93	23	78	57	3	65	24	64	59	66	.15	−2.9	5	9,499	sw.	31	sw.	8	16	11	4	4.0	.0	.0
Canton	448	10	61	29.50	29.97		69.0	−1.5	92	23	81	46	26	57	37				1.99	−1.5	6	5,179	sw.	27	sw.	28	9	14	8	5.1	.0	.0
Ithaca	836	74	100	29.12	30.01		73.1	+2.6	98	31	86	50	4	60	34	64	59	66	4.59	+1.0	15	5,410	nw.	35	nw.	31	7	12	12	5.8	.0	.0
Oswego	335	71	85	29.63	29.99	+.03	72.0	+1.6	91	23	80	57	19	64	26	64	59	64	.93	−2.0	4	5,792	s.	31	n.	30	8	18	5	5.0	.0	.0
Rochester	523	86	102	29.45	30.01	+.04	74.3	+3.6	99	23	84	55	4	64	31	63	56	55	.43	−2.5	5	6,083	sw.	24	w.	29	15	14	2	3.9	.0	.0
Syracuse	596	65	79	29.38	30.01	+.04	75.5	+4.7	98	23	86	54	11	65	31				.30	−3.4	4	5,224	s.	21	nw.	5	7	20	4	5.3	.0	.0
Erie	714	130	166	29.26	30.01	+.03	73.6	+2.6	97	23	82	58	4	66	24	66	62	67	1.12	−1.9	5	8,285	w.	39	e.	3	23	5	3	2.5	.0	.0
Cleveland	762	267	337	29.21	30.01	+.02	74.5	+3.1	96	23	82	60	3	67	22	64	57	56	1.26	−2.2	4	8,562	n.	48	n.	2	17	7	7	3.8	.0	.0
Sandusky	629	5	67	29.36	30.02	+.03	75.4	+2.0	100	23	86	56	17	65	30				1.46	−2.0	8	5,773	ne.	25	ne.	2	13	12	6	4.2	.0	.0
Toledo	628	79	87	29.35	30.02	+.03	75.0	+1.8	99	23	85	57	17	65	27	65	59	60	2.13	−.9	6	6,027	w.	23	w.	23	22	6	3	2.8	.0	.0
Fort Wayne	857	69	84	29.11	30.02		75.4	+1.9	98	23	86	55	17	65	29	65	58	60	3.39	−.2	6	5,413	ne.	21	ne.	2	14	13	4	4.3	.0	.0
Detroit	730	218	258	29.26	30.03	+.05	75.4	+3.3	98	23	85	57	3	66	28	64	57	57	2.47	−.8	6	6,744	sw.	22	ne.	2	13	17	1	4.1	.0	.0
Upper Lake Region							**70.7**	**+2.6**										**68**	**2.73**	**−0.4**										**4.5**		
Alpena	609	13	89	29.36	30.02	+.05	69.8	+3.9	98	31	81	48	18	59	34	63	59	69	2.10	−.7	9	6,551	nw.	32	sw.	23	13	14	4	3.9	.0	.0
Escanaba	612	54	60	29.35	30.00	+.03	68.2	+2.2	87	28	77	45	18	59	26	62	58	71	3.04	−.3	7	6,732	s.	35	n.	6	8	16	7	5.1	.0	.0
Grand Rapids	707	70	244	29.27	30.01	+.03	75.6	+3.3	96	23	86	55	25	65	29	65	60	60	2.78	−.1	6	7,224	sw.	36	nw.	23	14	13	4	3.8	.0	.0
Lansing	878	6	88	29.09	30.01		72.2	+1.3	96	23	84	50	25	60	31	65	61	70	1.43	−1.7	6	5,306	sw.	27	w.	22	13	16	2	3.5	.0	.0
Marquette	734	77	111	29.20	29.99	+.03	66.0	+1.1	99	29	76	48	18	56	39	60	56	71	1.55	−1.6	10	6,024	w.	25	sw.	29	7	13	11	5.7	.0	.0
Sault Sainte Marie	614	11	52	29.33	30.01	+.04	67.0	+3.2	95	31	78	46	18	56	34	60	56	72	1.66	−1.2	10	4,626	nw.	23	nw.	14	12	10	9	4.8	.0	.0
Chicago	673	7	131	29.30	30.02	+.04	75.6	+3.1	94	23	83	60	17	68	26	66	62	67	2.70	−.6	7	6,673	ne.	38	nw.	2	16	9	6	3.6	.0	.0
Green Bay	617	109	141	29.33	29.99	+.02	73.0	+3.0	97	30	83	53	16	63	28	65	60	67	3.43	.0	10	7,114	sw.	29	ne.	19	10	10	11	5.5	.0	.0
Milwaukee	681	97	221	29.28	30.01	+.04	74.1	+4.0	95	30	82	60	16	66	25	65	59	62	4.55	+1.7	8	8,093	w.	33	se.	2	16	8	7	3.9	.0	.0
Duluth	1,133	5	47	28.77	29.97	+.02	65.3	+1.4	89	13	75	47	3	55	32	59	56	76	4.09	+.3	9	7,628	ne.	29	sw.	13	11	14	6	4.7	.0	.0
North Dakota							**72.9**	**+4.4**										**56**	**2.05**	**−0.5**										**3.4**		
Moorhead	940	50	58	28.93	29.92	−.02	73.7	+5.6	102	28	86	52	17	61	40	63	56	59	1.44	−2.0	7	5,591	s.	26	n.	10	16	12	3	3.8	.0	.0
Bismarck	1,674	8	57	28.17	29.91	−.02	73.9	+4.1	102	28	87	48	21	61	39	62	54	56	1.61	−.6	9	6,598	se.	38	s.	26	17	10	4	3.2	.0	.0
Devils Lake	1,478	11	44	28.39	29.94	+.01	70.8	+3.4	98	26	84	49	23	58	39	60	54	61	2.58	.0	14	6,511	s.	31	nw.	5	12	16	3	3.9	.0	.0
Grand Forks	833	12	67				71.8		99	28	86	46	21	58	43	62			1.35		8		nw.	26	se.	4	7	20	4		.0	.0
Williston	1,878	41	48	27.96	29.89	−.03	73.2	+4.3	103	26	87	48	15	59	37	59	49	49	2.57	+.7	10	5,721	se.	32	nw.	19	21	10	0	2.7	.0	.0
Upper Mississippi Valley							**77.4**	**+2.3**										**64**	**3.19**	**−0.4**										**4.2**		
Minneapolis	918	102	208	28.97	29.93		77.0	+4.7	100	30	88	57	8	66	28				2.16	−1.6	9	7,267	s.	34	nw.	12	10	16	5	4.9	.0	.0
La Crosse	714	11	48	29.21	29.96	.00	74.6	+1.8	95	30	85	52	16	64	32	66	63	71	5.43	+1.5	9	3,404	s.	14	sw.	29	15	9	7	4.2	.0	.0
Madison	974	70	78	28.98	29.99	+.02	73.6	+1.5	94	30	83	58	16	64	24	65	60	64	3.33	−.6	8	5,545	sw.	31	ne.	2	16	6	9	4.2	.0	.0
Wausau	1,247	4	62	28.69	30.00		73.7		99	30	86	50	16	61	34				1.92	−2.4	9	4,655	sw.	30	e.	21	13	6	12	5.0	.0	.0
Charles City	1,015	10	51	28.93	29.97	+.01	75.1	+2.8	95	30	86	52	16	64	30	67	62	66	2.87	−.9	7	4,582	se.	27	n.	1	13	12	6	4.2	.0	.0
Davenport	606	118	143	29.35	30.00	+.03	77.6	+2.3	95	22	88	58	25	68	29	67	61	61	1.56	−1.8	7	5,766	sw.	37	nw.	14	16	8	7	4.2	.0	.0
Des Moines	861	5	99	29.08	29.96	.00	78.0	+2.6	99	1	89	58	16	67	31	68	62	63	4.06	+.6	9	6,158	s.	27	e.	1	15	10	6	4.3	.0	.0
Dubuque	700	81	96	29.26	29.99	+.02	75.6	+1.5	95	30	86	57	25	66	29	66	61	63	3.84	−.1	7	4,391	s.	28	nw.	2	15	7	9	4.3	.0	.0
Keokuk	614	64	78	29.34	30.00	+.02	78.4	+1.5	96	1	88	62	25	69	25	68	62	61	1.61	−1.8	6	4,887	sw.	22	sw.	31	15	11	5	3.9	.0	.0
Cairo	358	87	93	29.60	29.97	−.03	79.4	−.2	100	2	87	65	18	71	22	71	67	70	7.49	+4.4	9	5,134	s.	24	sw.	23	12	7	12	5.3	.0	.0
Peoria	609	11	45	29.36	30.02	+.04	78.5	+3.1	97	23	91	58	16	66	35	67	62	64	1.93	−1.6	7	4,039	ne.	19	w.	2	20	9	2	2.5	.0	.0
Springfield, Ill	636	5	191	29.32	29.98	.00	80.4	+3.9	101	1	92	61	5	69	28	68	62	60	.42	−2.4	3	7,297	s.	31	n.	14	8	20	3	4.4	.0	.0
St. Louis	568	265	303	29.38	29.97	−.02	81.2	+2.6	103	2	90	65	4	72	29	70	65	62	4.63	+1.6	4	7,381	sw.	28	s.	31	18	8	5	3.6	.0	.0
Missouri Valley							**79.2**	**+3.1**										**60**	**3.09**	**−0.7**										**3.7**		
Columbia, Mo	784	6	84	29.16	29.97	−.01	79.7	+2.8	100	1	91	58	17	69	31				1.02	−2.5	6	5,254	s.	18	n.	14	19	11	1	3.3	.0	.0
Kansas City	963	10	86	28.96	29.95	−.02	80.9	+2.8	103	1	90	62	26	72	24	68	62	56	1.13	−3.0	3	5,872	s.	31	nw.	7	15	12	4	3.8	.0	.0
St. Joseph	967	11	49	28.94	29.94		80.0		102	1	90	59	26	70	31	69	63	61	2.59	−1.1	5	5,579	se.	23	nw.	7	20	9	2	3.1	.0	.0
Springfield, Mo	1,324	98	104	28.59	29.96	−.02	78.3	+1.5	100	2	87	64	18	70	24	69	65	66	4.17	.0	6	6,292	s.	24	sw.	8	13	15	3	3.9	.0	.0
Iola	984	11	50	28.92	29.93	−.04	81.8	+3.6	106	2	94	60	26	70	33				4.16	+.4	9		s.				15	10	6		.0	.0
Topeka	987	65	87				81.2	+3.4	106	1	93	60	26	70	35				2.47	−1.8	8	6,364	s.	27	sw.	30	16	12	3	3.5	.0	.0
Lincoln	1,189	11	81	28.71	29.93	−0.2	78.6	+2.1	108	1	90	57	26	67	30	68	63	65	5.63	+1.8	10	6,401	s.	37	e.	11	14	11	6	3.7	.0	.0
Omaha	1,105	115	122	28.81	29.95	.00	78.8	+2.1	101	1	89	62	26	69	29	68	62	60	5.03	+1.5	7	5,027	s.	30	n.	11	17	9	5	3.6	.0	.0
Valentine	2,598	47	54	27.29	29.94	+0.1	77.8	+4.1	108	28	92	51	2	64	41	63	55	55	2.43	−.6	10	7,143	s.	34	ne.	1	17	9	5	3.9	.0	.0
Sioux City	1,135	94	164	28.75	29.93	−.02	77.4	+3.1	97	29	88	56	16	66	31	67	62	63	3.20	−.3	11	7,743	s.	32	n.	22	12	12	7	4.2	.0	.0
Huron	1,306	59	74	28.56	29.93	−.01	77.0	+5.2	110	29	91	55	21	63	41	64	57	58	2.12	−1.0	7	7,310	se.	44	nw.	19	13	13	5	4.1	.0	.0
Northern Slope							**72.6**	**+4.7**										**45**	**0.72**	**−0.9**										**3.0**		
Billings	3,140	5					75.4		108	25	96	46	1	55	53				.38		4		nw.				19	10	2		.0	.0
Havre	2,505	11	67	27.33	29.90	−0.01	72.7	+4.4	107	25	89	45	20	57	48	55	42	41	.37	−1.5	4	6,408	e.	33	nw.	3	22	8	1	2.3	.0	.0
Helena	4,124	85	111	25.81	29.89	−.04	71.7	+6.0	99	25	86	46	1	57	37	54	41	37	.41	−.7	3	6,439	sw.	43	sw.	8	19	11	1	2.8	.0	.0
Kalispell	2,973	48	56	26.94	29.93	.00	66.6	+2.5	96	26	82	43	30	51	39	52	40	46	.21	−.9	2	5,103	nw.	35	sw.	9	18	12	1	2.4	.0	.0
Miles City	2,371	48	55		29.90	−.02	79.2	+6.3	106	26	92	55	20	66	36			38	.49	−1.0	4	4,705	ne.	30	n.	19	26	5	0		.0	.0
Rapid City	3,259	50	58	26.62	29.93	.00	76.5	+5.5	102	28	90	51	21	63	39	62	52	47	2.05	−.3	7	5,601	w.	27	sw.	2	18	10	3	3.4	.0	.0
Cheyenne	6,088	84	101	24.13	29.94	+.02	70.2	+3.5	93	29	83	48	23	57	33	55	46	50	1.31	−.8	8	7,319	s.	46	w.	22	12	12	7	4.6	.0	.0
Lander	5,372	60	68	24.71	29.90	−.02	72.5	+5.1	98	24	89	47	2	56	45	55	42	41	.99	+.3	4	4,121	sw.	35	sw.	13	20	10	1	2.6	.0	.0
Sheridan	3,790	10	47	26.10	29.91		72.8		102	25	90	45	21	55	48	58	47	40	.25	−1.0	4	3,662	se.	22	nw.	19	23	8	0	2.2	.0	.0
Yellowstone Park	6,241	11	48	23.99	29.96	+.04	65.6	+4.1	91	25	82	39	1	49	42	49	37	44	.21	−1.1	8	6,151	sw.	27	sw.	19	19	9	3	3.1	.0	.0
North Platte	2,821	11	51	27.07	29.92	−.01	78.2	+5.3	104	28	92	56	16	65	42	65	58	50	.94	−1.8	5	5,748	se.	29	n.	22	17	11	3	3.7	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, July 1933*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Middle Slope							**80.2**	**+3.1**										**54**	**2.11**	**−0.7**										**3.5**		
Denver	5,292	106	113	24.82	29.94	+.03	75.2	+3.0	97	28	87	55	23	63	33	58	47	46	.90	−.8	9	5,679	s.	37	nw.	14	14	15	2	3.6	.0	.0
Pueblo	4,685	80	86	25.36	29.92	+.01	77.5	+3.3	100	13	92	54	30	63	41	59	49	47	1.98	.0	8	5,254	se.	35	nw.	16	12	18	1	3.9	.0	.0
Concordia	1,392	50	58	28.52	29.95	.00	80.6	+2.6	110	1	92	58	26	69	32	69	64	62	3.94	+.2	6	5,693	s.	34	nw.	7	12	17	2	3.8	.0	.0
Dodge City	2,509	10	86	27.40	29.92	−.01	81.9	+3.5	108	1	95	56	27	69	33	66	59	53	1.75	−1.4	10	7,995	s.	31	se.	5	26	5	0	1.9	.0	.0
Wichita	1,358	85	93	28.52	29.91	−.05	82.5	+3.1	105	2	93	62	26	72	28	69	63	58	2.34	−1.0	3	7,923	s.	30	n.	13	15	11	5	3.9	.0	.0
Oklahoma City	1,214	10	47	28.66	29.90	−.06	83.5	+2.9	107	11	94	64	26	73	26	71	65	61	1.73	−1.1	5	6,572	s.	22	ne.	13	17	9	5	3.8	.0	.0
Southern Slope							**83.7**	**+2.5**										**53**	**0.62**	**−1.8**										**3.9**		
Abilene	1,738	10	52	28.13	29.88	−.05	85.1	+2.3	109	14	98	62	28	73	34	69	62	54	.94	−1.2	6	6,318	s.	27	sw.	31	16	12	3	3.8	.0	.0
Amarillo	3,676	10	49	26.29	29.91	−.01	82.3	+5.5	104	13	95	63	27	70	35	64	56	50	.66	−2.2	6	6,631	s.	29	se.	30	14	15	2	4.2	.0	.0
Big Spring	2,537	5	62	27.34	29.88	----	83.3	----	108	14	96	63	26	70	33	67	60	53	1.51	----	7	----	s.	----	----	----	19	8	4	3.5	.0	.0
Del Rio	944	64	71	28.87	29.82	−.08	86.7	+.4	103	14	97	69	28	77	28	72	65	56	.11	−2.3	3	7,142	se.	25	se.	27	9	15	7	5.4	.0	.0
Roswell	3,566	75	85	26.36	29.87	−.01	80.6	+1.7	102	14	94	61	58	67	34	64	55	50	.79	−1.5	8	5,410	se.	27	w.	30	21	9	1	2.6	.0	.0
Southern Plateau							**82.1**	**+3.1**										**46**	**0.73**	**−0.4**										**3.3**		
El Paso	3,778	152	175	26.16	29.82	−.02	84.0	+2.9	104	12	96	66	17	72	30	64	54	42	1.34	−.6	7	6,297	e.	40	ne.	24	18	10	3	3.4	.0	.0
Albuquerque	4,972	51	66	25.09	29.82	----	77.8	----	98	11	92	58	29	64	34	61	52	51	2.04	----	11	6,159	se.	36	nw.	30	15	15	1	3.6	.0	.0
Santa Fe	7,013	38	53	23.38	29.88	.00	70.6	+1.6	90	11	83	52	28	58	32	55	46	49	2.00	−.4	17	4,516	e.	24	ne.	24	6	21	4	5.1	.0	.0
Flagstaff	6,907	10	59	23.46	29.86	+.03	67.4	+2.4	88	11	82	47	4	53	37	55	----	64	3.12	----	18	5,282	n.	25	n.	27	1	18	12	----	.0	.0
Phoenix	1,108	10	107	28.62	29.73	−.05	95.0	+5.2	113	26	108	74	3	82	33	71	59	34	.30	−.8	5	4,993	w.	27	ne.	26	19	10	2	3.1	.0	.0
Yuma	141	9	54	29.58	29.72	−.04	93.6	+2.8	115	26	108	66	3	79	39	71	59	37	T	−.2	0	4,506	sw.	25	se.	28	28	3	0	1.3	.0	.0
Independence	3,957	5	26	25.94	29.87	+.04	81.8	+3.7	104	13	98	54	1	65	41	57	----	----	T	−.1	0	----	s.	----	----	----	22	6	3	----	.0	.0
Middle Plateau							**77.7**	**+5.3**										**34**	**0.83**	**+0.3**										**2.5**		
Reno	4,532	74	81	25.46	29.84	−.03	75.8	+8.3	101	23	94	48	10	58	44	53	36	31	.25	.0	2	6,043	w.	27	sw.	2	28	1	2	1.2	.0	.0
Tonopah	6,090	12	20	----	----	----	77.8	----	97	14	89	56	7	66	28	54	36	27	.30	----	2	----	se.	----	----	----	----	----	----	----	.0	.0
Winnemucca	4,344	18	56	25.59	29.87	−.03	76.2	+5.6	103	24	96	49	1	57	46	53	34	28	.06	−.2	2	5,462	sw.	21	se.	26	28	2	1	1.2	.0	.0
Modena	5,473	10	46	24.65	29.84	−.02	74.4	+3.8	98	13	90	43	1	59	41	57	46	46	2.15	+1.1	12	7,313	sw.	40	sw.	24	7	22	2	4.4	.0	.0
Salt Lake City	4,360	86	210	25.61	29.86	−.04	81.3	+5.6	101	25	94	57	1	69	32	60	46	34	.18	−.3	6	5,553	s.	35	sw.	9	20	8	3	3.0	.0	.0
Grand Junction	4,602	60	68	25.39	29.88	−.01	80.9	+3.2	102	13	95	61	7	67	35	60	46	37	1.50	+.9	11	5,155	se.	28	s.	10	22	6	3	2.9	.0	.0
Northern Plateau							**74.0**	**+3.4**										**36**	**0.22**	**−0.3**										**1.7**		
Baker	3,471	48	53	26.46	29.97	+.02	68.2	+2.6	101	24	85	43	31	51	46	53	41	43	T	−.6	0	5,131	n.	17	sw.	9	28	3	0	1.2	.0	.0
Boise	2,739	79	87	27.10	29.88	−.05	76.4	+3.5	108	24	93	53	1	60	42	56	40	33	T	−.2	0	4,059	nw.	16	nw.	8	26	5	0	1.2	.0	.0
Pocatello	4,477	60	68	25.48	29.86	−.06	76.4	+5.6	100	26	92	52	1	61	42	55	38	30	1.05	+.3	4	6,490	s.	32	sw.	31	20	10	1	2.4	.0	.0
Spokane	1,929	101	110	27.93	29.93	−.03	71.8	+2.8	101	24	86	49	5	58	43	55	42	41	.17	−.5	1	5,012	sw.	21	sw.	29	20	9	2	2.3	.0	.0
Walla Walla	991	57	65	28.88	29.93	−.04	76.6	+2.6	104	15	90	54	31	63	41	58	42	34	.04	−.4	2	4,283	s.	22	w.	9	24	7	0	1.6	.0	.0
Yakima	1,076	58	67	28.81	29.94	----	74.4	+3.0	103	15	89	52	30	60	38	56	41	35	.06	−.3	3	5,410	nw.	19	nw.	3	27	3	1	1.5	.0	.0
North Pacific Coast Region							**62.1**	**+0.2**										**68**	**0.75**	**0.0**										**3.4**		
North Head	211	11	56	29.88	30.10	+.02	55.2	−2.0	62	11	58	49	23	52	11	53	51	88	.83	−.2	9	11,731	n.	40	s.	29	10	11	10	5.5	.0	.0
Port Angeles	29	8	53	----	30.10	----	57.3	----	81	15	65	44	5	50	27	----	----	----	.73	+.2	3	6,537	sw.	21	w.	9	19	4	8	----	.0	.0
Seattle	125	90	321	29.93	30.06	+.02	64.2	+1.1	86	15	74	52	5	54	28	55	48	61	1.13	+.5	3	6,163	ne.	28	s.	1	14	12	5	3.6	.0	.0
Tatoosh Island	86	10	54	30.01	30.11	+.06	54.0	−1.1	72	15	58	48	30	50	21	52	50	90	2.54	+1.0	11	6,160	sw.	26	e.	15	8	13	10	5.9	.0	.0
Medford	1,329	29	58	28.55	29.92	----	73.2	----	104	14	91	47	10	55	46	59	49	51	T	−.4	0	4,689	nw.	26	nw.	2	28	3	0	.8	.0	.0
Portland, Oreg.	153	68	106	29.88	30.03	−.02	68.0	+1.3	94	15	79	52	22	57	34	58	52	60	T	−.6	0	5,595	nw.	19	nw.	14	21	4	6	3.2	.0	.0
Roseburg	510	75	99	29.46	30.01	−.02	69.0	+1.6	94	14	84	46	10	54	36	57	49	56	.0	−.3	0	4,212	n.	18	n.	6	26	3	2	1.5	.0	.0
Middle Pacific Coast Region							**69.3**	**+2.4**										**61**	**T**	**0.0**										**2.2**		
Eureka	62	73	89	29.96	30.03	−.02	54.4	−1.1	62	3	58	49	7	51	11	52	51	90	T	−.1	0	5,108	nw.	19	sw.	31	10	12	9	5.1	.0	.0
Red Bluff	330	5	58	29.45	29.79	−.10	86.8	+6.0	111	27	103	61	2	70	41	62	44	28	.01	.0	1	4,626	n.	16	se.	2	29	0	2	.6	.0	.0
Sacramento	69	106	117	29.73	29.80	−.08	77.6	+4.4	110	26	96	53	2	60	47	60	49	46	T	.0	0	6,315	s.	20	sw.	31	31	0	0	.3	.0	.0
San Francisco	155	208	243	29.72	29.89	−.06	59.5	+1.0	82	11	67	49	25	52	26	54	51	79	.00	.0	0	5,786	sw.	21	w.	3	15	11	5	3.7	.0	.0
San Jose	141	12	110	29.74	29.89	----	68.4	+1.5	96	11	83	49	10	54	41	----	----	----	.00	.0	.0	4,876	nw.	18	sw.	31	31	0	0	1.1	.0	.0
South Pacific Coast Region							**73.5**	**+0.3**										**62**	**0.01**	**0.0**										**3.2**		
Fresno	327	89	98	29.44	29.78	−.05	85.6	+3.5	114	27	102	59	3	69	38	62	45	30	T	.0	0	5,921	nw.	21	nw.	30	29	2	0	.6	.0	.0
Los Angeles	338	159	191	29.54	29.89	−.01	69.4	−.8	93	26	78	55	4	60	25	62	58	74	T	.0	0	4,060	sw.	13	w.	25	20	10	1	3.0	.0	.0
San Diego	87	62	70	29.79	29.88	−.04	65.4	−1.8	78	26	70	58	1	61	14	61	59	82	.02	.0	1	4,905	sw.	15	w.	9	4	16	11	5.9	.0	.0
West Indies																																
San Juan, P.R.	82	9	54	29.92	30.00	----	80.8	+.7	90	15	85	74	5	77	15	----	----	----	2.62	−3.3	19	10,958	e.	38	ne.	25	3	20	8	6.2	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	----	[1] 29.85	+.03	79.5	−.8	89	7	85	71	5	74	15	----	----	[1] 88	6.01	−1.2	18	3,108	nw.	19	n.	29	1	6	24	8.0	.0	.0
Cristobal	36	6	97	----	[1] 29.85	+.01	81.0	+.6	90	21	86	74	12	76	14	76	75	[1] 84	9.88	−5.7	23	3,916	se.	22	nw.	30	0	6	25	8.4	.0	.0
Alaska																																
Fairbanks	454	68	87	----	[2] 29.88	----	58.3	----	88	28	70	36	19	47	35	----	----	64	1.39	−.5	10	4,856	sw.	26	s.	3	8	7	16	----	.0	.0
Juneau	80	11	50	[2] 29.92	[2] 30.01	----	53.9	----	73	15	59	43	7	48	25	50	48	83	3.67	----	24	4,543	s.	23	se.	16	2	5	24	8.5	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 30.03	[2] 30.07	----	75.3	−2.4	81	18	80	69	18	71	12	68	65	72	.88	−.3	21	7,467	e.	25	e.	10	7	22	2	4.9	.0	.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, July 1933*

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
Cape Race, N.F.	99												
Sydney, C.B.I.	48	29.94	29.99	+0.06	63.0	+0.7	74.8	51.2	85	38	2.90	−0.75	0.0
Halifax, N.S.	88	29.90	30.00	+.04	63.0	−.4	72.2	53.8	83	40	2.40	−1.65	.0
Yarmouth, N.S.	65	29.89	29.96	+.01	61.3	+1.8	70.2	52.5	76	45	3.07	−.40	.0
Charlottetown, P.E.I.	38	29.90	29.94	+.04	65.4	+1.3	73.1	57.8	80	48	.42	−3.07	.0
Chatham, N.B.	28	29.84	29.87	−.01	65.2	+.2	77.0	53.4	84	42	.76	−3.43	.0
Father Point, Que.	20	29.90	29.92	+.07	59.1	+1.5	67.8	50.5	83	44	2.30	−.74	.0
Quebec, Que.	296	29.66	29.98	+.07	66.9	+1.4	76.1	57.7	88	49	2.38	−1.88	.0
Doucet, Que.	1,236				60.3		76.4	44.1	86	28	3.20		.0
Montreal, Que.	187												
Ottawa, Ont.	236	29.72	29.98	+.04	70.1	+.6	80.9	59.3	95	52	2.89	−.58	.0
Kingston, Ont.	285	29.68	29.98	+.01	70.6	+2.4	80.1	61.1	92	54	1.83	−1.06	.0
Toronto, Ont.	379	29.59	29.98	+.01	72.9	+4.9	83.8	62.0	98	54	1.53	−1.39	.0
Cochrane, Ont.	930				63.3		74.8	51.8	89	35	2.97		.0
White River, Ont.	1,244	28.69	29.98	+.04	60.6	+1.1	74.6	46.6	86	33	4.38	+1.58	.0
London, Ont.	808				69.6		81.8	57.5	96	47	2.54		.0
Southampton, Ont.	656	29.30	30.01	+.04	68.4	+3.7	78.9	57.8	96	46	.80	−1.18	.0
Parry Sound, Ont.	688	29.32	30.00	+.04	69.5	+3.5	80.0	59.0	94	49	1.70	−.92	.0
Port Arthur, Ont.	644	29.28	29.99	+.05	63.7	+1.7	72.6	54.8	86	46	5.89	+2.41	.0
Winnipeg, Man.	760	29.11	29.92	−.01	69.1	+3.1	81.3	56.9	91	47	1.61	−1.47	.0
Minnedosa, Man.	1,690	28.15	29.92	−.01	66.4	+4.2	78.9	53.0	94	40	2.01	−.59	.0
Le Pas, Man.	860				64.0		74.9	53.1	87	43	2.20		.0
Qu'Appelle, Sask.	2,115	27.65	29.86	−.06	65.4	+1.9	79.1	51.7	98	40	.80	−1.68	.0
Moose Jaw, Sask.	1,759				68.7		83.7	53.8	105	40	.35		.0
Swift Current, Sask.	2,392	27.39	29.85	−.06	67.6	+1.1	83.7	51.6	104	38	.66	−1.78	.0
Medicine Hat, Alb.	2,365	27.41	29.84	−.06	69.9	+2.1	84.6	55.2	104	42	.24	−1.85	.0
Calgary, Alb.	3,540												
Banff, Alb.	4,521	25.43	29.93	+.03	57.5	+.9	73.0	42.0	90	31	1.08	−2.16	.0
Prince Albert, Sask.	1,450	28.37	29.92	+.01	64.7	+2.8	76.1	53.3	89	42	1.39	−.66	.0
Battleford, Sask.	1,592	28.19	29.90	.00	65.4	+.7	81.0	49.8	100	38	.64	−1.70	.0
Edmonton, Alb.	2,150												
Kamloops, B.C.	1,262	28.67	29.93	−.01	68.5	.0	82.4	54.5	99	44	.48	−1.13	.0
Victoria, B.C.	230												
Barkerville, B.C.	4,180												
Estevan Point, B.C.	20				53.8		58.5	49.1	64	49	1.46		.0
Prince Rupert, B.C.	170				53.2		59.8	46.6	72	42	6.16		.0
Hamilton, Ber.	151	30.02	30.18	+.04	80.2	+1.5	85.7	74.7	90	69	4.21	−.23	.0

LATE REPORTS FOR JUNE 1933

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
Father Point, Que.	20	29.79	29.81	−0.06	54.1	+1.1	62.3	45.9	86	36	5.09	+2.11	0.0
Quebec, Que.	296												
Doucet, Que.	1,236				57.2		73.0	41.3	90	22	2.98		.0
Cochrane, Ont.	930				60.0		72.8	47.2	90	30	1.14		.1
White River, Ont.	1,244	28.61	29.90	−.04	61.5	+2.8	76.3	46.7	97	24	2.20	−.02	.0
Southampton, Ont.	656	29.23	29.94	−.03	62.5	+2.1	72.4	52.6	90	40	.97	−1.38	.0
Parry Sound, Ont.	688	29.24	29.92	−.04	64.7	+3.0	76.1	53.4	89	37	2.94	+.52	.0
Minnedosa, Man.	1,690	28.09	29.87	−.02	64.6	+5.0	76.4	52.7	97	33	2.67	−.33	.0
Le Pas, Man.	860				62.1		73.8	50.5	93	38	1.50		.0
Qu'Appelle, Sask.	2,115												
Moose Jaw, Sask.	1,759				66.7		79.9	53.5	102	36	2.89		.0
Banff, Alb.	4,521	25.34	29.84	.00	53.5	+2.0	67.2	39.8	86	27	1.40	−1.93	.0
Estevan Point, B.C.	20				52.7		65.1	40.3	78	29	4.06		.0
Prince Rupert, B.C.	170				50.6		57.1	44.2	63	37	6.28		.0
Hamilton, Ber.	151	29.88	30.04	−.08	76.5	+1.5	81.5	71.6	86	68	4.63	−1.32	.0

SEVERE LOCAL STORMS, JULY 1933

[Compiled by Mary O. Souder]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Tipton, Iowa	1	A.m.		1	$6,000	Electrical	Telephone exchange destroyed by fire after being struck by lightning; man and cow killed by lightning.	Official, U.S. Weather Bureau.
Providence and Pawtucket, R.I.	1	3:35-4:20 p.m.				Thunderstorm	Lightning struck a house in Pawtucket and trees at the Metacomet Golf Course in East Providence.	Do.
La Crosse, Wis., 5 miles south.	1	5-10 p.m.	[1]5		50,000	Hail	2 persons injured by hailstones the size of walnuts; crops damaged.	Do.
Coldwater, Iowa	1	7 p.m.			8,500	Tornado	No details	Do.
Reedsburg, near, Wis.	1	7:30 p.m.	55-440		5,000	Tornado and rain	House, several barns and smaller buildings damaged; many trees uprooted.	Do.
Crawford, Richland, and Sauk Counties, Wis.	1	7:30-8 p.m.			75,000	Hail	Serious damage to growing crops	Do.
Wright, Franklin, Floyd, and Dubuque Counties, Iowa.	1	10:30-12p.m.		2	309,000	Tornado	Telephone and power lines disabled; damage to buildings; several persons injured; loss to livestock.	Do.
Mosalem, Iowa	1	P.m.	[1]2			Hail	Telephone poles and trees blown down; gardens badly beaten.	Do.
New York City and vicinity.	1	do.				Thundersquall	Portion of Riverside Park and depressions and underpasses in Central Park flooded; police launch rescued 6 from rough waters of the Bronx; fishing boat with party of 50 disabled 13 miles from Ambrose Lightship; 2 homes in Garden City, Long Island, struck by Lightning; lightning set fire to 3 oil tanks in Elizabeth city, N.J.; in Astoria, Long Island, a circus tent with 400 spectators, mostly children, blew down, injuring 12 persons, 2 seriously; hundreds of trees blown down and cellars flooded.	Do.
Williamsport and Lycoming Valley, Pa.	1	do.			50,000	Electrical and heavy hail.	Farm buildings destroyed and trees struck by lightning; several persons injured.	Do.
Parkersburg, W.Va.	1	do.				Severe thunderstorm and wind.	Several dwellings struck by lightning; much damage to trees.	Do.
Brodhead, near, Wis.	1				1,000	Hail	Property damaged	Do.
Green Lake, Columbia, Fond du Lac, Dodge, and Sheboygan Counties, Wis.	1				25,000	Wind	Trees uprooted; orchards ruined; buildings wrecked.	Do.
La Crosse-Prairie du Chien, Wis.	1				100,000	Wind, rain, and hail.	Many buildings damaged or demolished by wind; loss to crops; highways washed.	Do.
Cheraw, near, S.C.	1			1	500	Thunderstorm	One man killed, another injured by lightning; barn burned.	Do.
Dubuque, Iowa, and vicinity.	1-2	10:05 p.m.-4 a.m.				Tornadic winds, electrical and rain.	Electric light service cut off and telephones out of commission; considerable damage to farm buildings, windmills and growing crops; bridges and culverts washed out; $5,000 damage to streets and sewers.	Do.
Chicago, Ill., and vicinity.	2	3:03-3:20 a.m.			1,000,000	Electrical, heavy rain, and hail.	Power lines torn down, 4 persons injured; many trees uprooted; basements and subways flooded; 28 houses unroofed and 36 fires broke out due to damaged wires; grandstand and 2 pylons demolished at Chicago Airport; hangar at Elgin Airport lifted by wind.	Do.
Chanute, Kans.	2	P.m.				Tornado and rain.	Farm buildings damaged	Do.
Gettysburg, Pa., and vicinity.	2	do.			20,000	Tornadic winds	3 cottages demolished, more than 200 trees uprooted; house unroofed.	
Page County, Va.	2			2	6,000	Hail and wind	Damage to crops and buildings; 2 children killed by lightning.	Do.
Norfolk, Va.	2-3	P.m.			5,000	Wind and rain	Part of downtown business section flooded; high tides and huge waves damaged jetties, bridges and resort property at nearby beaches; numerous small boats destroyed.	Do.
Pondera and Toole Counties, Mont.	3	P.m.	[1]1½-6		40,000	Hail, electrical	Property damaged; few cattle killed by lightning.	Do.
Fate, Tex.	4	5 p.m.	1,320		25,000	Tornado	5 persons injured; small loss of crops	Do.
Florence, Colo.	4			1	15,000	Electrical and heavy rain.	Damage to roads and property; 1 person killed by lightning.	Do.
Natchitoches, La.	4-5	P.m.				Wind	Buildings unroofed and tenant houses blown down causing damage of several thousand dollars.	Do.
Millett, Tex.	5					Tornado	Report incomplete; damage estimated to be small.	Do.
Cavour, S.Dak.	6	3:45 p.m.	[1]2	1	40,000	Thunder squall	Damage to buildings and crops	Do.
Platte, S.Dak.	6	P.m.				Tornado	Telegraph and telephone wires torn down; roof of Milwaukee railroad depot torn off; windows in roundhouse blown in, 2 persons injured.	Do.
Scobey, Mont.	6		[1]2		35,000	Heavy hail	Damage mostly to grain crops and gardens	Do.
Ekalaka, Mont, near	8	5 p.m.		1		Wind	Girl crushed beneath wreckage of a small farm outbuilding; no other damage reported.	Do.
Missoula, Mont.	8	6 p.m.			10,000	Wind, rain, and hail.	Telephone and power service crippled; windows shattered and many roofs damaged.	Do.
Helena, Mont.	8	6:55-7:45 p.m.				Thundersquall and hail.	Sewers plugged; dirt roads washed out in places.	Do.
Harvey County, Kans.	8	7 p.m.	[1]1		5,000	Tornado	Chief damage to farm buildings and implements; path 3½ miles long.	Do.
Franklin County, Kans.	8	9:30-10 p.m.	[1]5		10,000	Heavy hail and wind.	Property damaged; some loss of crops; path 15 miles long.	Do.
Springfield, Mo., and vicinity.	8	P.m.		1		Thunderstorm and heavy hail.	Traffic tied up due to flooded streets; house struck by lightning.	Do.
Franklin and Floyd Counties, Iowa.	8				2,800	Wind and hail	Details of damage not reported	Do.
Bluff City, Kans., and vicinity.	9	5 p.m.	880		1,000	Tornadic winds	Storm had tornadic characteristics; several large barns blown down; path 10 miles long.	Do.
Lewis County, Idaho	9	5:30 p.m.	[1]7		30,000	Hail	Considerable damage to grain; path 7 miles long.	Do.
Newton, Kans., and vicinity.	9	7 p.m.				3 tornadoes and heavy rain.	Barns, windmills, and outbuildings blown down; trees uprooted; 2 boys whirled into the air and carried from the barn to the house yard by the second tornado; several thousand dollars' damage.	Do.

[1] Miles instead of yards.

Severe local storms, July 1933—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Williamsburg, Kans., and vicinity.	9	8 p.m.	[1] 4		5,000	Tornadic winds	Wire service interrupted; trees damaged	Official, U. S. Weather Bureau.
Lake Ronkonkoma, Brookhaven, N.Y.	9	P.m.				Tornado and hail	Telephone and electric poles down; several persons injured; trees uprooted, crops ruined; group of bathers so badly bruised by downpour of hailstones as large as marbles that a doctor had to be called.	Do.
Western Whitman County, Wash.	9	do				Hail, rain, and wind.	Grain flattened in fields; roads washed out; water carried away poultry; orchards damaged; severe loss in limited areas.	Do.
Eastern Long Island, N.Y.	9					Thunderstorm	Buildings unroofed; many trees and poles blown down; some damage to crops.	Do.
Harpersfield, N.Y.	10					Severe hailstorm	Vegetation severely damaged	Do.
Hartley, Iowa, and vicinity.	11	1 p.m.	[1] 10			Wind, hail, and rain.	Extensive damage to telephone wires; many large trees uprooted; small buildings demolished; loss to crops	Do.
Odebolt, Iowa, and vicinity.	11	2 p.m.	[1] 12		2,000	Wind and hail	Electric and telephone poles broken off; many houses damaged by falling trees; loss to crops; cattle killed; path 12 miles long.	Do.
Yankton County, S.Dak.	11	5-6 p.m.	[1] 5	1	3,000	Thundersquall and hail.	Damage to property and some crop loss	Do.
Cedar and eastern Knox Counties, Nebr.	11	5:30-9:30 p.m.	[1] 15	1	600,000	Hail and wind	50,000 acres of crops destroyed; many farmers without stock feed; buildings wrecked.	Do.
Prairie Home, Nebr.	11	6:30-7 p.m.	[1] 4		2,000	do	Property damaged	Do.
Lincoln, Nebr.	11	6:45 - 7:30 p.m.	[1] 4		3,000	Wind	Light and telephone service disrupted; trees blown down and windows broken.	Do.
Sioux City, Iowa	11	7 p.m.		1		Electrical	Electric service disabled; lightning struck the chimney of a school killing 1 child and injuring 3 when clump of bricks and mortar fell in their midst.	Do.
Eastern Stanton and southern Wayne Counties, Nebr.	11	7-10 p.m.	[1] 2-7		220,000	Hail and wind	20,000 acres of crops destroyed; many farm buildings wrecked; much damaged by flooding.	Do.
O'Brien, Buena Vista, Ida, Sac, Crawford, and Shelby Counties, Iowa.	11				250,000	do	Crops completely destroyed in some small areas	Do.
Etowah, Tenn.	11				10,000	Electrical and heavy rain.	Streets and a number of stores flooded	Do.
Black River Falls, Wis.	12	2 p.m.			500	Hail	Loss to crops	Do.
Downsville, Wis., 2 miles northwest.	12		[1] 2-5		1,280	do	Damage to windows and roofs	Do.
Stevens County, Kans.	14	1:30-2 p.m.	[1] 4		2,000	Wind	Damage to windmills and small buildings; path 12 miles long.	Do.
Texas and Beaver Counties, Okla.	14	2-3 p.m.	[1] 10		65,000	do	Damage to buildings and other property; small loss of crops because of this storm, the section having been previously visited by sandstorms and crops had suffered for want of rain; path 35 miles long.	Do.
Paris, Tex.	14	3:30 a.m.	17		2,500	do	Buildings blown down and 2 airplanes damaged at airport.	Do.
Perryton-Pampa, Tex.	14	3:30-5:10 p.m.	[1] 10		251,000	do	Small loss to crops, only $1,000 damage reported at Pampa.	Do.
Quanah, Tex.	14	4 p.m.	[1] 4		100,000	Hail and wind	Small buildings blown down	Do.
Morehouse, Mo.	14	P.m.			25,000	Severe electrical	Plant of Hummelberger-Harrison Manufacturing Co. struck by lightning and burned.	Do.
Johnson County, Iowa	14				10,000	Wind and hail	Crops damaged	Do.
Guthrie, Mo.	14					Wind	Trees and outbuildings blown down; amount of damage not estimated.	Do.
Egerton and Black River Falls, Wis.	14				7,500	Thundersquall	Property damaged	Do.
Madison-McFarland and Hartford, Wis.	14				1,500	Hail	About 50 automobile tops damaged; windows broken; considerable loss to crops, especially corn and grain.	Do.
Milwaukee, Wis.	14					Electrical and rain.	Several houses, poles, and trees struck by lightning; basements flooded and sewers overflowed.	Do.
Cloverdale, near, N.Mex.	15	2 p.m.	[1] 2			Hail	Damage severe	Do.
Weld, Adams, Arapahoe, Elbert, and El Paso Counties, Colo.	16	2-6 p.m.	[1] 3-6		250,000	Rain and hail	Streams overflowed their banks; bridges destroyed; crops washed out; stones as large as hen's eggs caused severe damage to roofs, windows, trees, poultry, and livestock.	Do.
Thomas and Logan Counties, Kans.	16	4 p.m.	[1] 2		2,000	Heavy hail and wind.	Chief damage to corn crop; path 30 miles long	Do.
Smith County, Kans.	17	4-5 p.m.	[1] 4		45,000	Wind and hail	Chief damage to corn crop; many small buildings demolished; large number of poultry killed; path 8 miles long.	Do.
Norton and Phillips Counties, Kans.	17	4:30 p.m.	[1] 4		10,000	do	Wind damaged telephone poles and small farm buildings; loss to corn crop from hail; path 20 miles long.	Do.
Florence, Colo.	17	P.m.			15,000	Electrical	2 oil refinery tanks destroyed by lightning	Do.
Lexington, near, South Carolina.	17	do			1,000	Thunderstorm	4 members of 1 family injured by lightning and their home damaged.	Do.
Grant County, Kans.	18	do	[1] 3			Tornado and thundersquall.	Several small buildings blown down; path 10 miles long.	Do.
Redfield, S.Dak., 15 miles southwest.	19	7:15 p.m.			1,000	Wind	Damage to buildings	Do.
Crandon, S.Dak.	19	7:30 p.m.	[1] 3		20,000	do	Property damaged	Do.
Tulare, S.Dak.	19	8:30 p.m.	[1] 3-5		5,000	Tornadic winds	Several large barns, granaries, and small buildings wrecked.	Do.
Hitchcock, S.Dak.	19	9 p.m.	[1] 10		75,000	Tornadic winds	Trees uprooted and buildings demolished	Do.
Cavour, S.Dak.	19	9:15 p.m.	[1] 3		8,000	Wind	Damage to buildings	Do.
Clayton, N.Y., and vicinity.	19	P.m.				Tornadic winds	Telephone, telegraph, and electric service crippled; poles and trees blown down; shrubbery uprooted.	Do.
Gettysburg, S.Dak.	19	do	[1] 4			Hail, excessive rainfall.	Small bridges washed away; poultry and small livestock drowned or killed.	Do.
Casco and Kewaunee, Wis.	19	do			6,000	Heavy hail	Considerable damage to crops; few windows broken.	Do.

[1] Miles instead of yards.

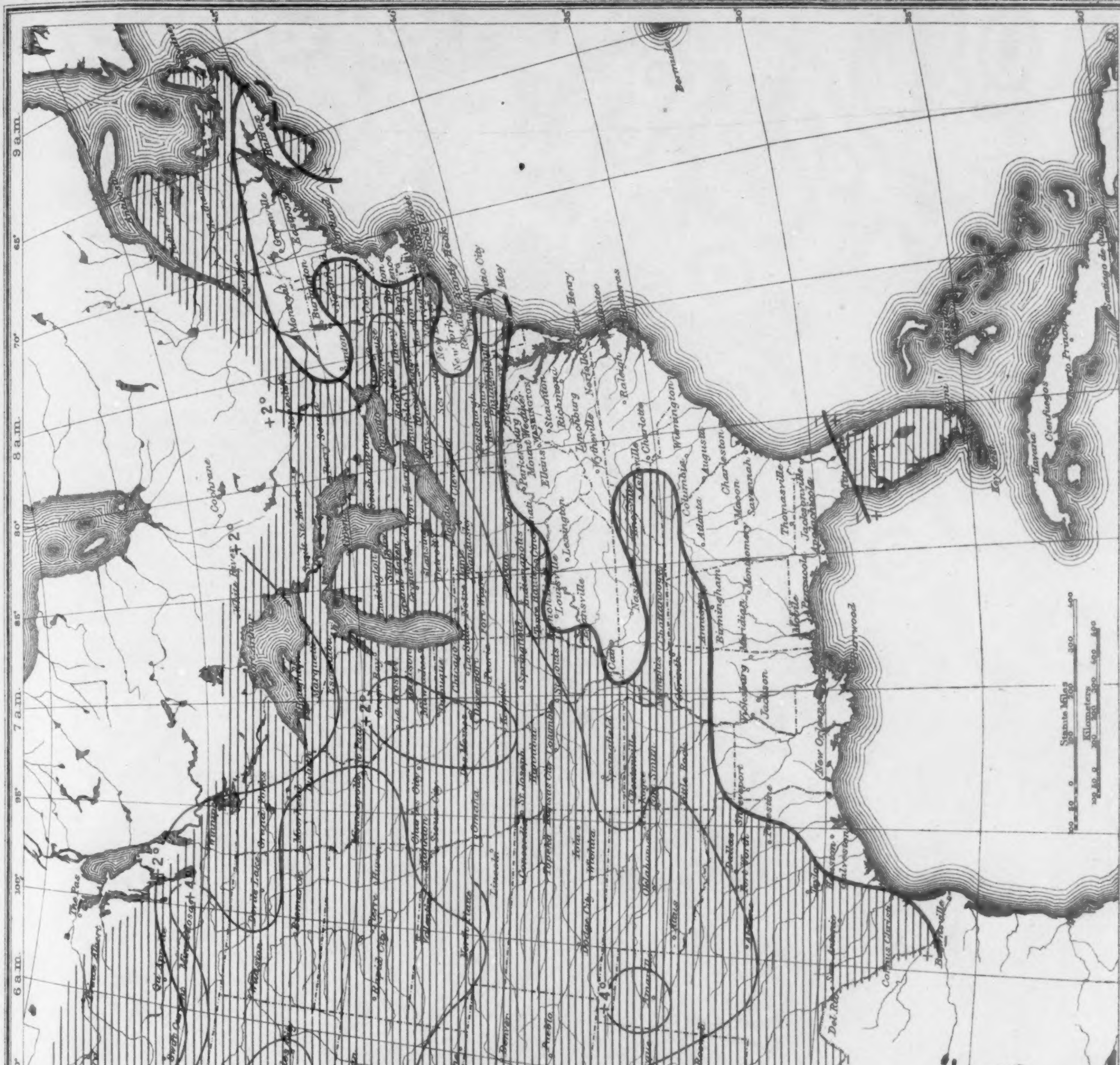
Severe local storms, July 1933—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
New York City, Mount St. Vincent and Yonkers, N.Y.	20	6 p.m.				Thunderstorm and hail.	Telephone poles down; flood held up traffic on the Hudson electric division of the New York Central between 6-7:30 p.m.; thousands of dollars damage to streets, homes, schools, automobiles, and gardens.	Do.
Westville, Mount Carmel, Waterbury, and Colchester, Conn.	20					do.	Transmission line and two churches struck by lightning; no fatalities.	Do.
Bloomer, Chetek, Almena, and Sand Creek, Wis.	20				9,000	Heavy hail	Loss to crops; buildings damaged	Do.
Datil, N.Mex.	21	1:30 p.m.	440			Hail	Roofs and crops damaged	Do.
North-Central Cheyenne County, Nebr.	21	8 p.m.	[1] 3		20,000	do.	Property destroyed	Do.
Rudolph and Wisconsin Rapids, Wis.	21		[1] 4		3,000	Thunderstorm	Property damaged	Do.
Hancock County, Iowa	21–22					Wind	Heavy damage reported	Do.
Cheyenne County, Nebr.	22	2-3 p.m.	[1] 2		60,000	Hail	Property damaged	Do.
Artesian, S.Dak.	22	2:30 p.m.	[1] 4			do.	Large hailstones damaged buildings, killed poultry and small livestock; crops destroyed.	Do.
Binghamton, N.Y.	22	2:51–4:22 p.m.				Thundersquall and hail.	Knickerbocker Building struck by lightning; streets flooded; small crop damage.	Do.
Lock Haven, Pa., and vicinity.	22	3-4 p.m.	[1] 6		100,000	Heavy hail	Loss solely to crops; hail largest and heaviest ever observed in this section.	Do.
Carthage, S.Dak.	22	P.m.	[1] 2		10,000	Hail and lightning.	Crops almost destroyed by hail; path 15 miles long.	Do.
Lyon County, Iowa	22				1,100	Wind	No details	Do.
Lebanon County, Pa.	22					Electrical	Much damage reported	Do.
Pittsburgh, Pa.	22					Thundersquall	Many places struck by lightning; wind in excess of 70 miles per hour recorded at the airport.	Do.
Blanchardville, Wis., southwest of.	22				8,000	Electrical	Large barn and contents struck by lightning and burned.	Do.
Grand Rapids, Mich.	23	3:03-3:06 p.m.				Hail and wind	Many shade trees uprooted; windows broken	Do.
Prescott, Ark.	23	3:40 p.m.	100		3,000	Tornado	Property damaged; path 1 mile long	Do.
East Lansing, Mich.	23	P.m.				Thundersquall	Trees and buildings damaged	Do.
Miami, Ariz.	23					Wind	Several persons injured; roofs blown off and signboards demolished.	Do.
Nogales, Ariz.	23				2,000	do.	Damage mostly to utility poles and to shop windows.	Do.
Keuka Lake, N.Y.	23			3		Severe thunderstorm.	14 sailboats sank or ran aground	Do.
Shreveport, La.	23–25				1,500,000	Rain	Buildings and much farm land flooded; resulting in loss mostly to cotton crop; highways washed.	Do.
Windham, Ohio, vicinity of.	24	1 a.m.				Tornadic winds	Considerable damage to trees, buildings, and other property; barn 30 by 60 feet picked up and whirled around.	Do.
Scranton, Pa.	24	3:20-4 p.m.				Heavy rains	Much damage from flooding reported	Do.
Alexandria, La.	24–25	P.m.				Wind and rain	Damage to roofs; interior of some buildings damaged because of torrential rains.	Do.
Elmira, N.Y.	24	P.m.			8,000	Rain, hail, and wind.	Telephone and electric service disrupted; trees blown down; large house struck by lighting and burned.	Do.
Ida County, Iowa	24				5,000	Hail	No details	Do.
Muskingum County, Ohio.	24					Severe electrical, wind, and rain.	Much damage to telephone poles; sewers overflowed.	Do.
Philadelphia, near, Pa.	25	4-6 p.m.		2		Electrical and rain	Lightning caused the death of 2 men; damage chiefly from flooding.	Do.
Fluvanna and Nottoway Counties, Va.	25				8,000	Hail and wind	Damage to fields, gardens, and timber	Do.
Norfolk, Va.	26	1:48-3:45 p.m.				Thunderstorm	Traffic delayed; sewers overflowed	Do.
Montgomery, Ala.	26				1,000	Thundersquall	Trees uprooted, roofs crushed, and street car traffic blocked by falling trees; several plate glass windows shattered.	Do.
Cloverdale, near, N.Mex.	29	4 p.m.	[1] 2			Hail	Severe damage to growing crops	Do.
Fort Worth, Tex.	30			1		Rain	7-year-old girl swept into a storm sewer, while wading up to her waist in water in a low section of the pavement near her home, and was drowned.	Do.
Oak Cliff, Dallas, Tex.*	30	4:15 p.m.	35	4	500,000	Tornado	30 persons badly injured; 50 residences totally demolished; path 4 blocks long.	Do.
Miami-Titusville, Fla.	30	P.m.			1,000,000	Wind	Communications interrupted; shrubbery uprooted; wind velocity 60 miles per hour recorded between Stuart and Fort Pierce.	Do.
Oswego N.Y.	30					Thundersquall	Damage to wires and trees; wind velocity of 41 miles an hour registered.	Do.
Kiowa County, Okla.	31	5 p.m.			25,000	Heavy hail	Damage to crops; path 6 miles long	Do.
Canton, N.Y., and vicinity	31	P.m.			5,000	Electrical	Barn struck by lightning and burned	Do.
Ludington, Mich.	31					Wind	Grandstand unroofed and many trees uprooted	Do.
Marlette, Fabius, Cazenovia, Norrisville, Sangerfield, and Waterville, N.Y.	31					Wind, hail, and rain.	Wires and poles blown down; trees uprooted; a house in Sangerfield carried 1,000 feet into a neighboring field; 250 hens killed when a barn was blown on a chicken house.	Do.
Milwaukee, Wis.	31					Wind and rain	Overhead wires were reported blown down; basements flooded; sewers overflowed; pavements buckled and highways inundated.	Do.
Monroe, Wis., northwest of.	31		[1] 1½		35,000	Thundersquall	Trees, barns, and silos blown down; crops flattened; path 9 miles long.	Do.

* For more detailed description of this storm see p. — MONTHLY WEATHER REVIEW, July 1933.

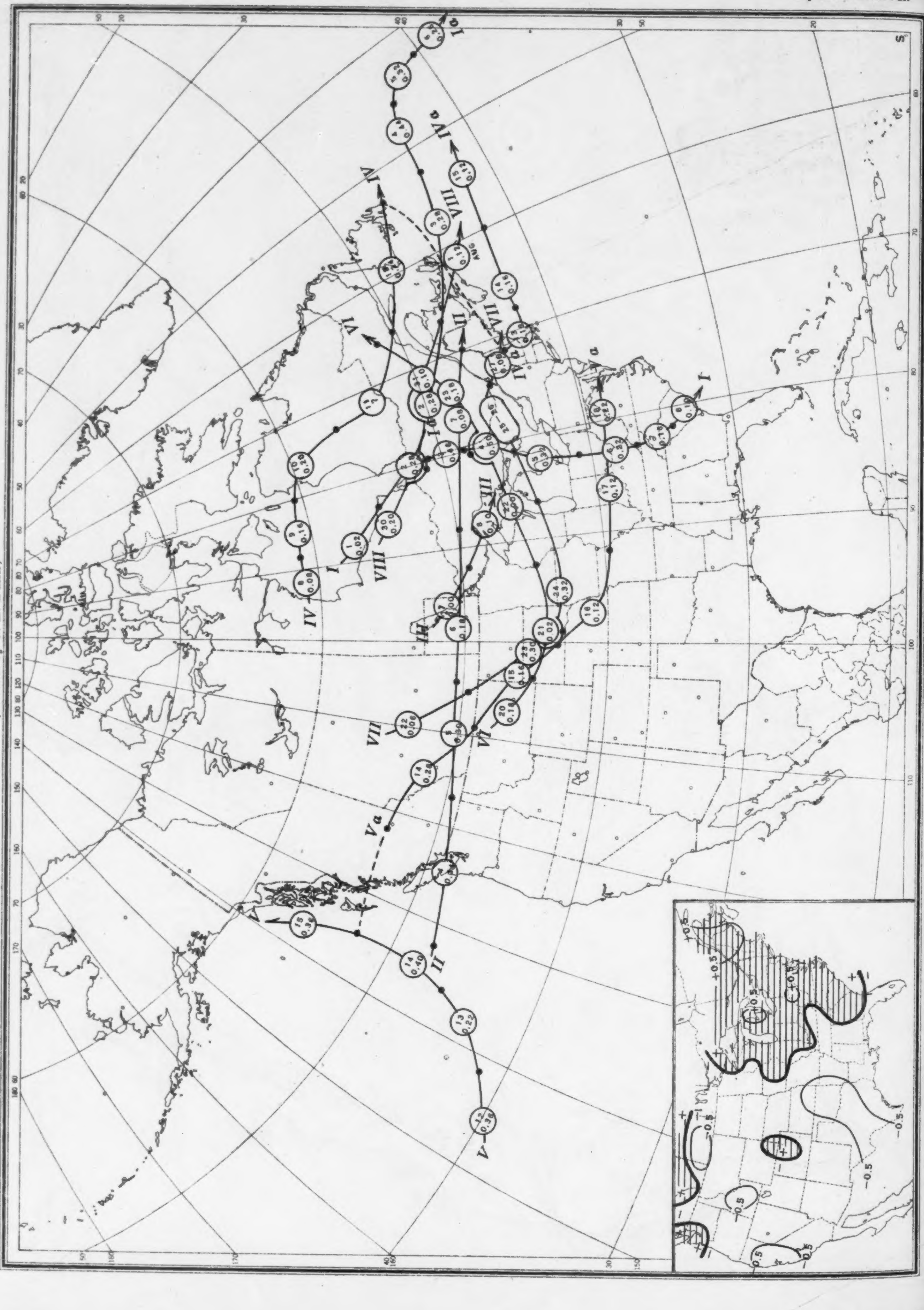
[1] Miles instead of yards.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, July 1933



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, July 1933. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by G. E. Dunn)

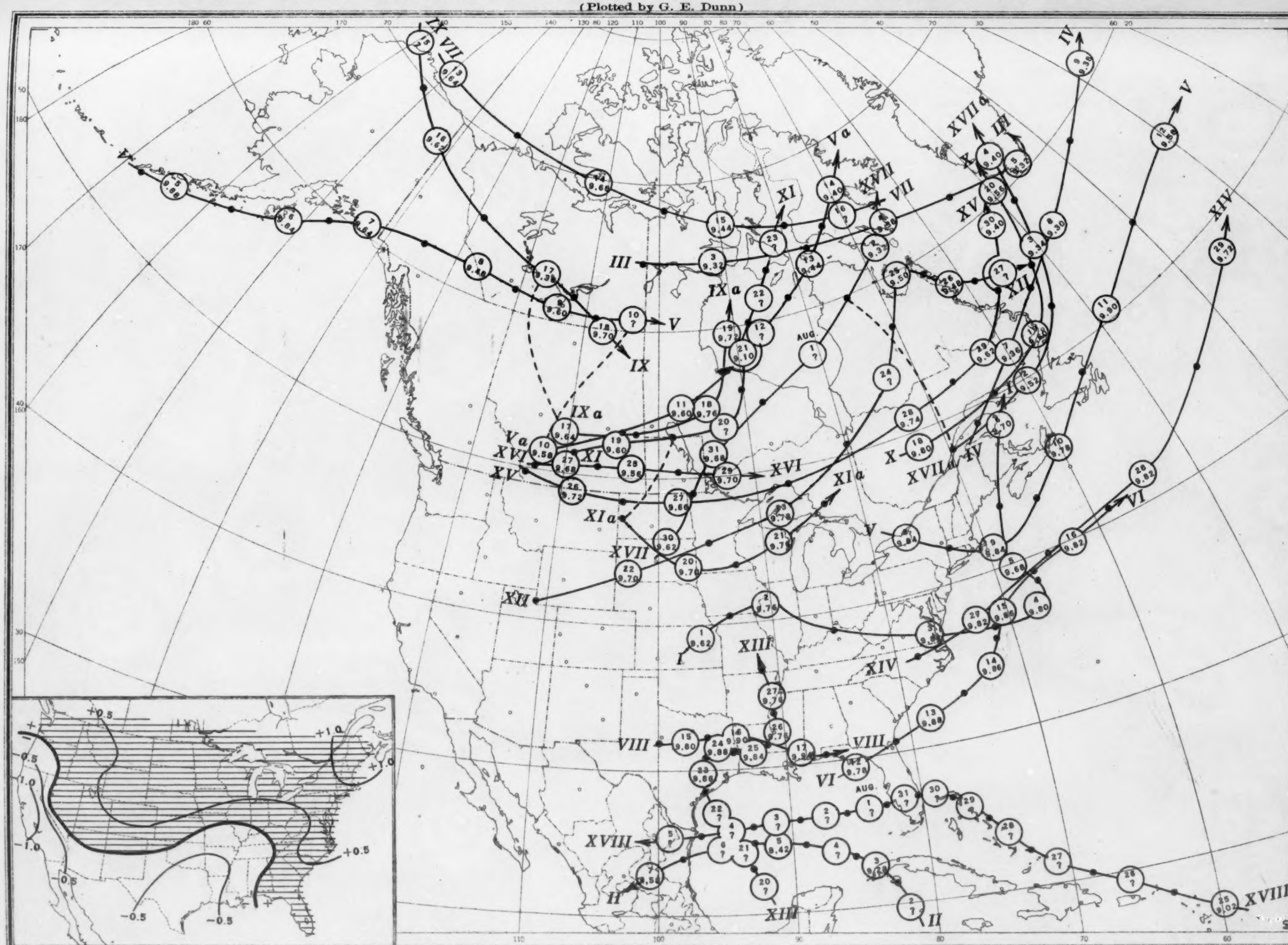


Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, July 1933. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by G. E. Dunn)

Chart III. Tracks of Centers of Cyclones, July 1933. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, July 1933

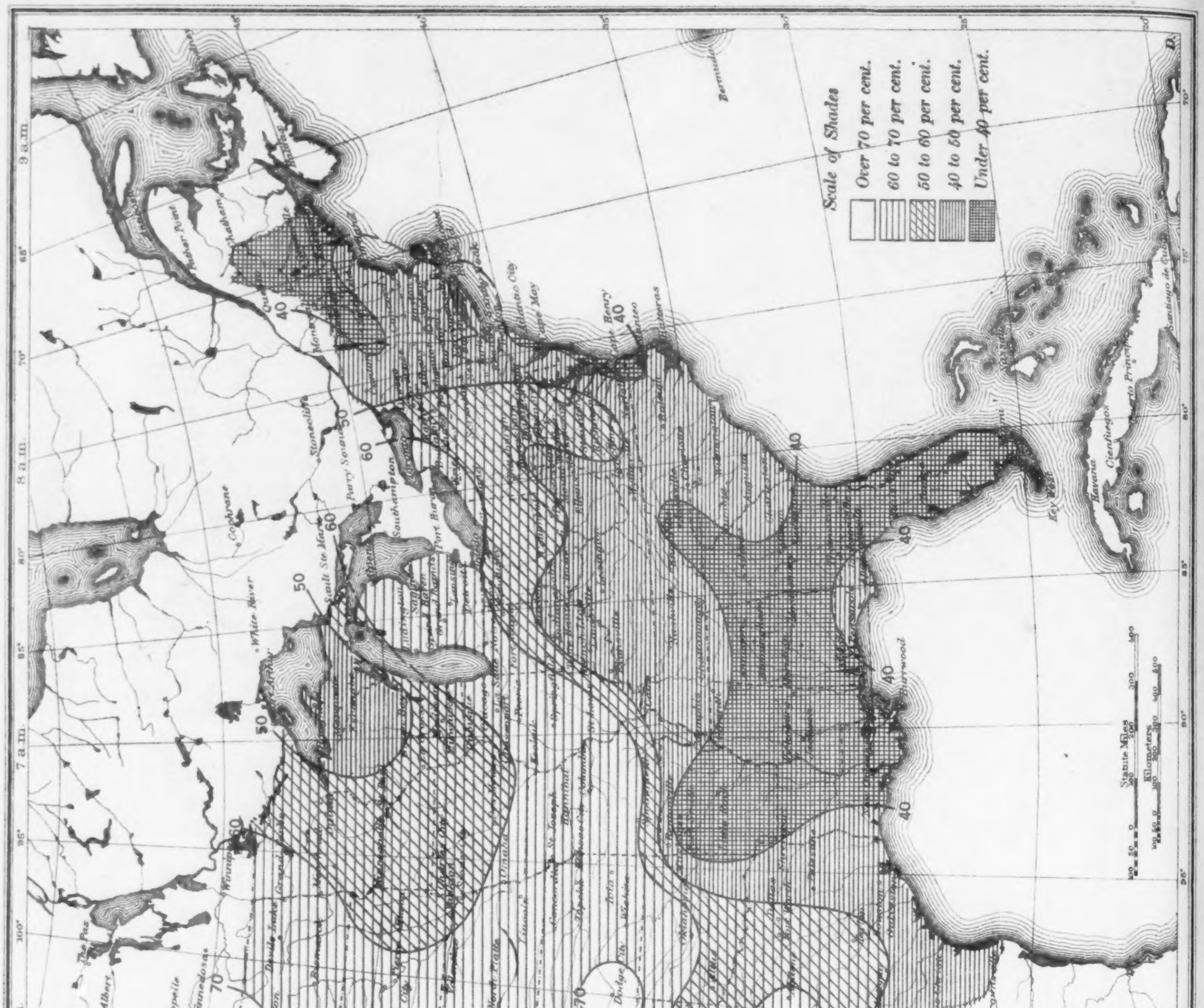


Chart V. Total Precipitation, Inches, July 1933. (Inset) Departure of Precipitation from Normal

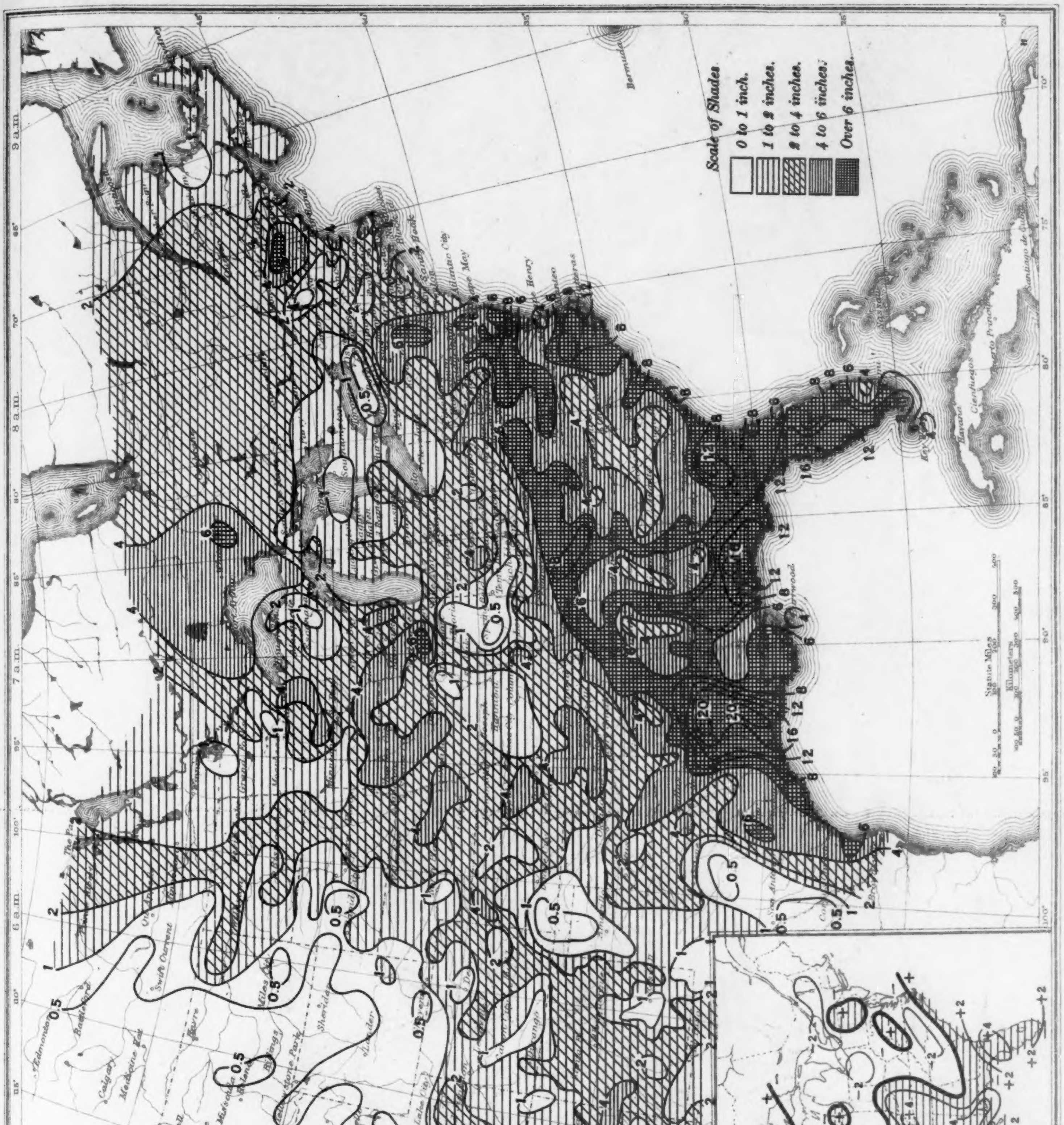


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, July 1933

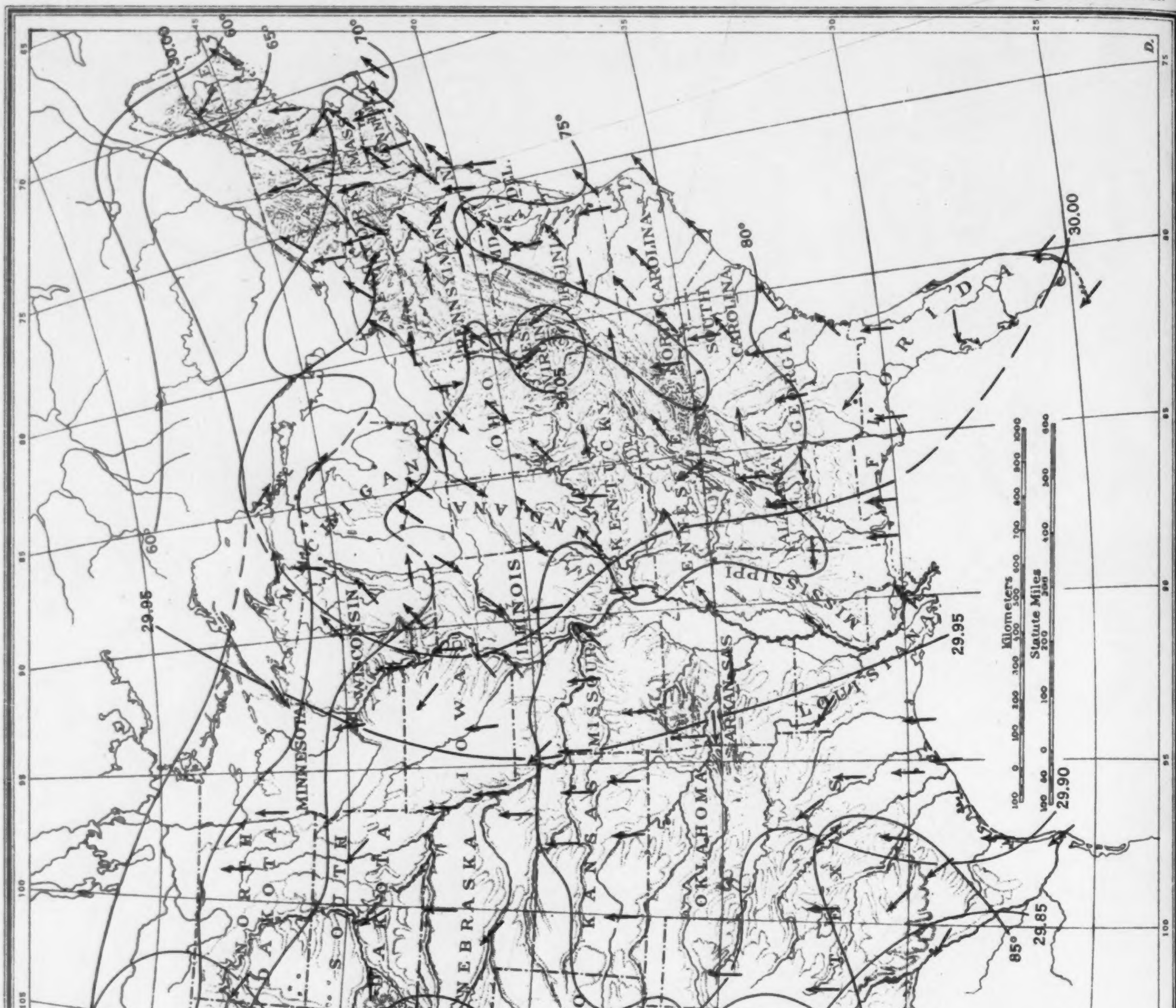


Chart VIII. Weather Map of North Atlantic Ocean, July 4, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

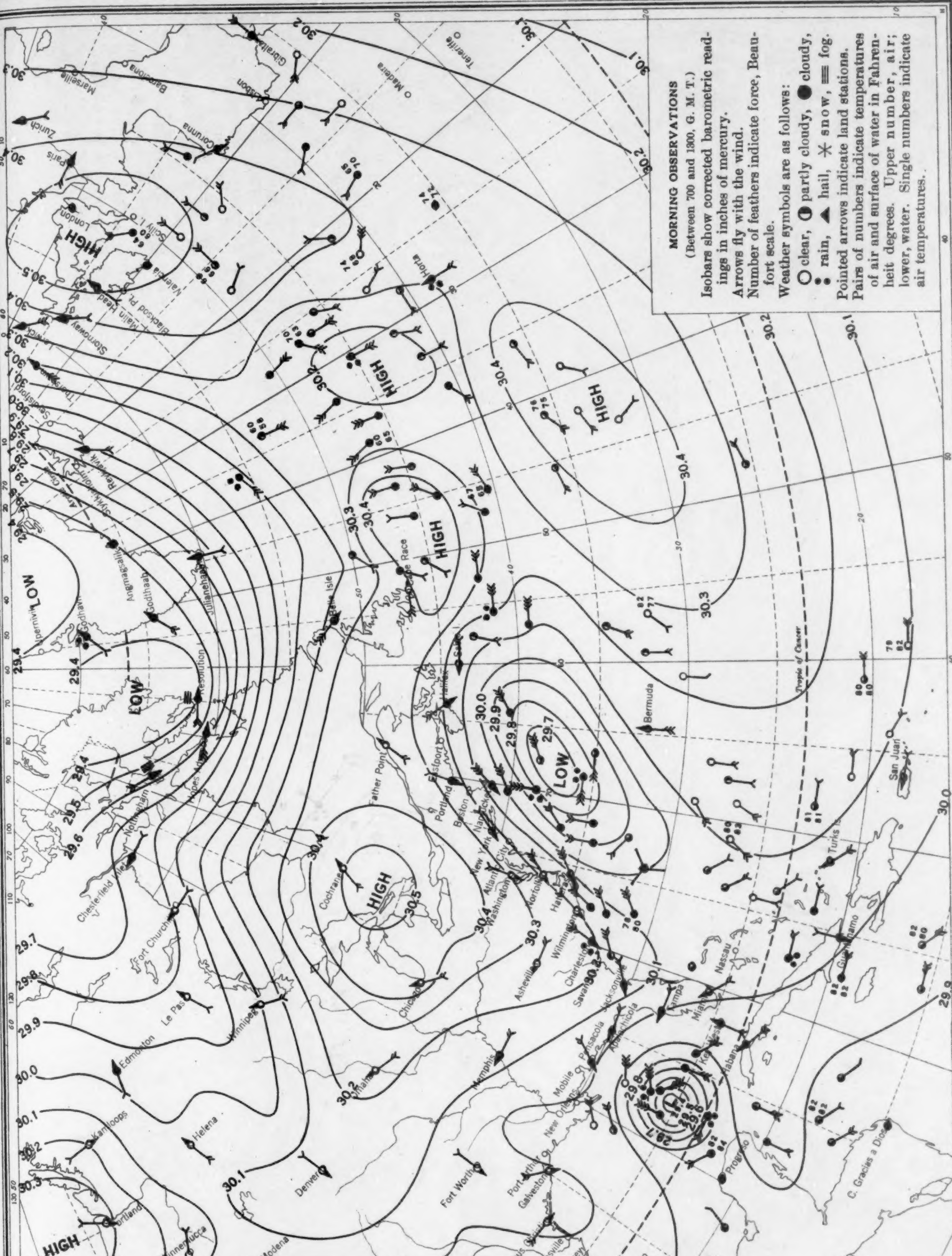


Chart IX. Weather Map of North Atlantic Ocean, July 12, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)

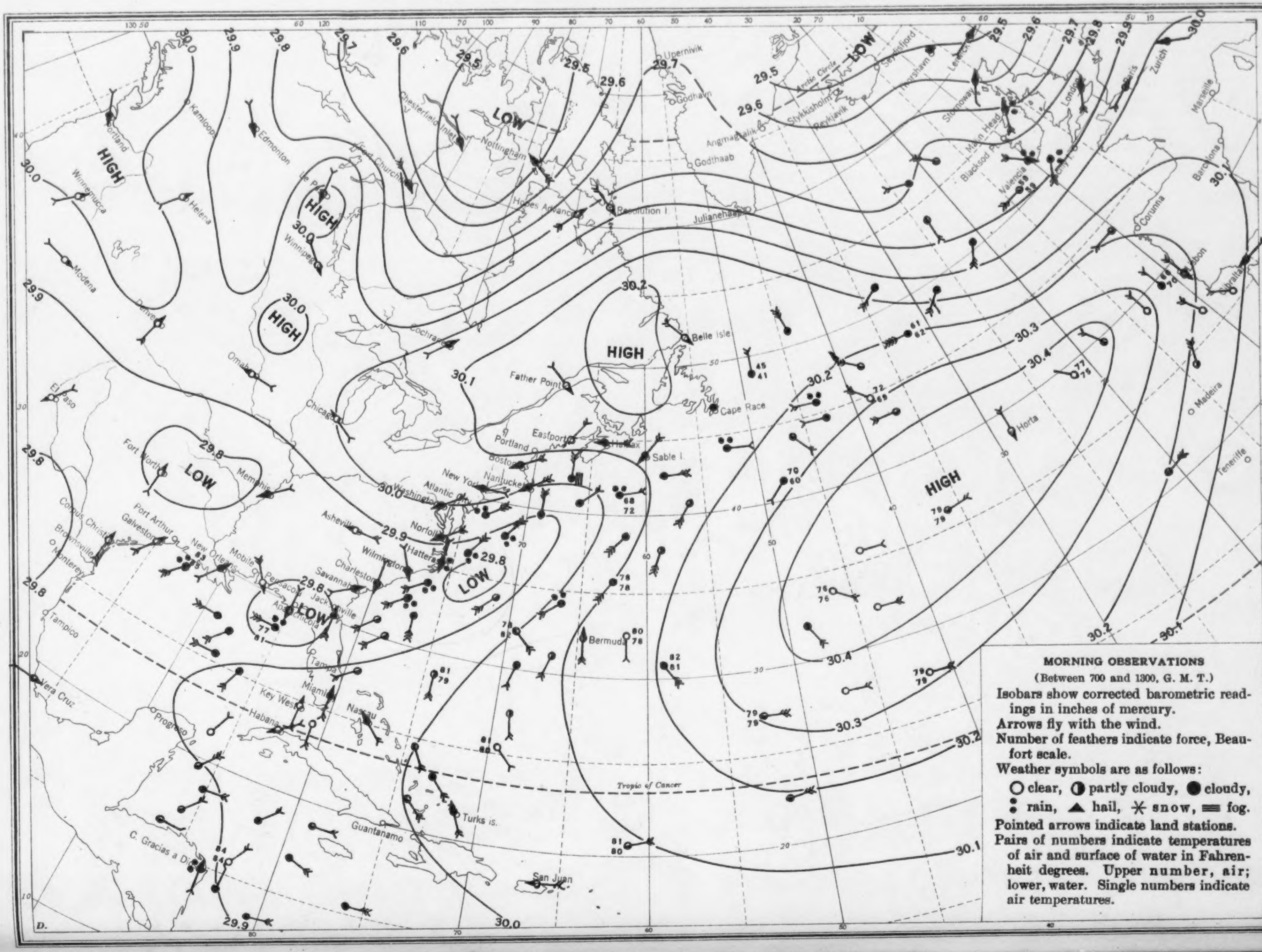


Chart X. Weather Map of North Atlantic Ocean, July 15, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

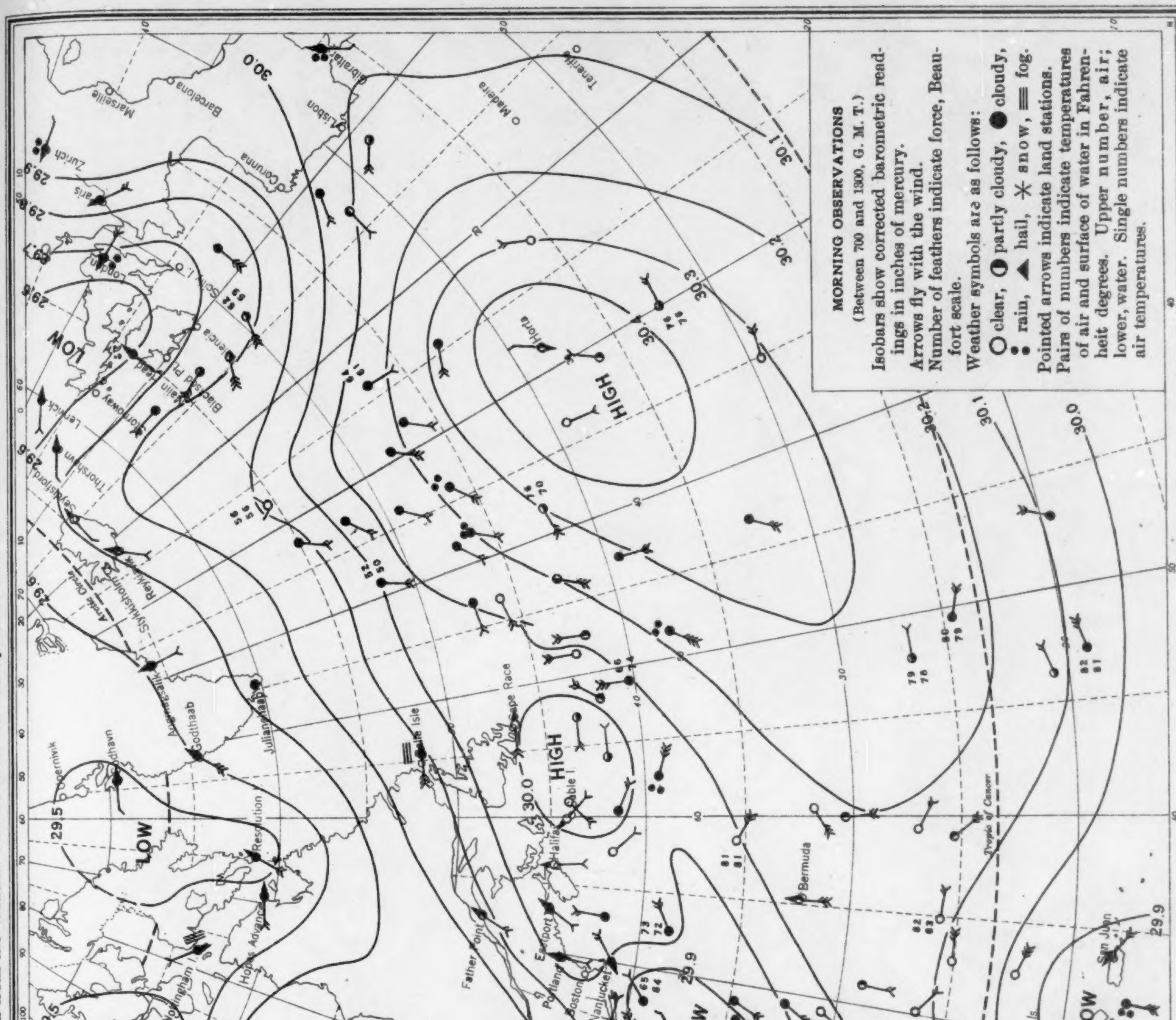


Chart XI. Weather Map of North Atlantic Ocean, July 31, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)